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ATOMIC WEAPONS RESEARCH ESTABLISHMENT

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REPORT No. T 62/57

OPERATION BUFFALO

Air and Ground Shock Measurements Group

Group Leader - N. S. Thumpston

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A.W.R.E.,
Aldermaston, Berks.

November, 1957

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United Kingdom Atomic Energy Authority

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Summary

At Operation Buffalo measurements were made of the hydrostatic pressure and pressure/time variation of the air shock wave along the main instrument lane using three types of gauge, and measurements of the drag pressure using a fourth type of gauge.

This report gives a brief description of the recording methods used and graphs of the peak positive pressure, duration and time of arrival of the air shock plotted against distance from Ground Zero.

In Rounds 1, 3 and 4 precursor-like waveforms were obtained and in these cases the records obtained are reproduced in the text.

From considerations of the pressure/distance data the Total Energy Yields of the weapons are estimated to be:-

Round 1 - 17 kilotons

Round 2 - 1 kiloton

Round 3 - $2\frac{1}{2}$ kilotons

Round 4 - 15 kilotons

The other activities of the Group included measurements of ground shock and determination of blast pressures from the observations on smoke rocket trails. These activities are reported separately.

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1. Introduction

The Air and Ground Shock Measurements Group (AG Group) at Operation Buffalo totalled 19 members. Fifteen, including the Group Leader and his Deputy, came from the Foulness Division of the Atomic Weapons Research Establishment and the other four were from the staff of the Suffield Experimental Establishment of the National Defence Research Board, Canada.

2. Object

The main task of the AG Group was the measurement of blast pressure and ground shock variables from which the performance of the weapons could be assessed and from which basic data on the effects of atomic weapons could be obtained.

The seven commitments of the Group were as follows:-

AG 1. To measure the hydrostatic pressure and pressure/time variation in the air shock wave, along the main instrument lane over an appropriate range of distances.

AG 2. To estimate the blast equivalence of each weapon from the velocity of the shock wave by a direct timing method.

AG 3. To observe precursor phenomena on appropriate Rounds (1, 3 and 4). This comprised the direct measurement of drag pressure and temperature variations in the air.

AG 4. To measure on Rounds 1 and 2 the variation with time of ground particle velocity and acceleration.

AG 5. and 6. To measure, for the Structures, Ordnance and other Target Response Groups, the pressure/time variation of air blast in and around structures and Service vehicles.

AG 7. To measure the maximum pressure in the free air shock wave from observations on smoke rocket trails.

Serials AG 1 to 6 were carried out by United Kingdom members of the Group and Serial AG 7 by the Canadian members.

This report deals with the observations that were made on Serials AG 1 and part of AG 3 (the drag pressure measurements). The remaining work will be reported separately.

3. Apparatus and Method

3.1 Blast Pressure Measurements

Two types of mechanical and one type of electronic gauge were used for blast pressure measurements. A photograph of a gauge site is shown in Figure 1.

3.1.1 Diaphragm Gauges

The mechanical diaphragm gauge records the deflection of a thin metal diaphragm by scribing a cylindrical lens on a moving celluloid strip with a shaped stylus, thereby giving directly a small pressure/time trace which could be magnified to convenient dimensions. The gauges used on Operation Buffalo were similar to those deployed on previous weapon trials with two modifications, both arising from trials experience. These were:-

(a) The inclusion of frequency-controlled mains-driven motors, coupled to a marker, so that a time trace was included on the record. This overcame the doubts of previous trials as to whether or not the motor driving the celluloid strip had maintained correct speed;

(b) the addition, over the diaphragm, of a cover in which there was a predetermined leak. By making the leak of suitable size the rate of build up of shock pressure on the diaphragm can be limited, to avoid the initial overshoot which had marred previous records, without introducing significant inaccurancies into the pressure/time variations received by the diaphragm. The size of the hole to provide this controlled leak was determined experimentally from field firings and shock tube work in the United Kingdom, and is critical.

At Maralinga, Mr. K. Darby was responsible for diaphragm gauges. The field requirements for the gauges were small. Each gauge required a mounting post and a cable connection to the rear of the instrument line for a time sequence starting signal at -30 sec, and for electrical power supply.

To avoid total loss of records from possible electrical generator failure, half of the gauges were connected to one generator and the remainder to a second generator.

3.1.2 Collapsible Tubes

The collapsible tubes measure peak pressure only, the principle being to relate the extent to which empty toothpaste tubes are crushed to the intensity of the blast wave to which they are subjected. Collapsible tubes have been used on all previous British trials.

The toothpaste tubes used on Operation Buffalo were made of aluminium and were smaller than those previously used, being only 8 cm long. They were purchased open-ended and were carefully folded in the United Kingdom to ensure uniformity of volume, after being preformed to a roughly rectangular shape to improve their sensitivity. The tubes were used in sets of nine in a hatchet-shaped baffle of new design (Figure 1). Two baffles were set out at each gauge station.

To measure the volume of the collapsed tubes after firing a water chain balance was made. The collapsed tubes were sealed and the buoyant tubes balanced under water against a length of submerged chain.

Mr. G. Harwood was the member of the Group responsible for tubes at Maralinga. Field requirements were small, being only two posts at each site for mounting the baffles.

Use of these tubes provides a simple method of measuring pressure but it must be noted that their behaviour varies with the shape of the wave to which they are subjected. The calibration from shock tube to Friedlander wave shape does not apply if the incident wave is multiple peaked.

3.1.3 Frequency Modulated Tape Recorder and Variable Inductance Gauge

The electronic gauge and recording assembly used on Operation Buffalo represented a new method of recording pressure/time relationships. The pressure sensitive head is a commercial variable inductance gauge mounted on an 8 in. long hatchet shaped baffle (Figure 1). The inductance forms part of an oscillatory circuit, variations of the frequency of which are recorded on magnetic tape. This system of recording has the virtue of being insensitive to radiation.

The frequency modulated tape recorder (FMT) was developed after experimental adaption of commercial components and was mounted on shock absorbers in a domed-top cylindrical container designed to withstand the expected pressures and ground shock (Figure 2). The recorder was mounted a few feet from the gauge element, thereby considerably reducing the cabling effort.

After the firings the tapes were collected and played back in the laboratory, the signal being displayed on a cathode ray oscillograph and photographed to give a permanent record. By playing the tape through slowly, interesting parts of the records could be reproduced with an extended time scale.

The FMT recording system was developed by the Deputy Group Leader, Mr. H. G. MacPherson, and was operated at Maralinga by Messrs. MacPherson, Turner and Pottinger. Field requirements for the FMT system were a gauge stand to carry the pressure head and a nearby hole for the FMT recorder in its container, the diameter of which was about 3 ft. In forward sites the shock-proof container was covered with sandbags. Each FMT site was coupled by a common cable to the rear of the instrument base to receive the initiating time sequence at -30 sec.

3.1.4 Drag Gauge

This gauge was used on Rounds 1, 3 and 4. It was designed to measure the stagnation pressure associated with the airflow behind the shock front and to assess the effect of sand in this airflow. The gauge (Figure 4) consists of a hollow cylindrical body, open at the front end, containing two recording pistons. The forward piston has a hole through which air flows to equalize the pressure on the front and back. This piston is intended not to react to the stagnation pressure but only to the direct impact of sand particles, thus recording the "sand pressure". The rear piston is shielded from the sand; its purpose is to record the difference between atmospheric and stagnation pressures. The pistons move against beryllium-copper springs on which are attached metal foil strain gauges. These strain gauges are connected to form a Wheatstone Bridge; the out-of-balance current, proportional to the pressure on the pistons, is recorded on photographic paper by a 6-channel recording mirror galvanometer.

The drag gauge was developed by Mr. G. Warren, who was also responsible for its use at Maralinga.

The gauges were mounted at two heights on heavy girders concreted into the ground in the region where a precursor was expected. They were connected, with 6-core cable, to the recorders (Figure 3) housed in a steel shelter about 4000 ft from Ground Zero.

3.2 Layout Arrangements at Maralinga

The blast pressure instruments were mounted on a series of prepared sites on the AG instrument lane. The lane was on the East side of the approach road running North to Ground Zero excepting the fore-end of the lane on Round 2, which was adjacent to the road on the West side. The lanes were 60 ft wide, with roughly graded surfaces. The gauge posts were set in concrete blocks, about 2 ft deep and 4 ft wide and of a length depending on the number of posts. The gauges were mounted with the FMT gauge nearest the road and the diaphragm gauge furthest from the road (see Figure 1).

Cable runs were made down each side of the lane, the power cable being kept separate from the time sequence and signal cable. Prior to firing, cables back to about the 10 p.s.i. level were buried.

When mounted on the posts the gauges were orientated so that the hatchet-shaped baffles were edge-on towards Ground Zero.

For the firings at One Tree (Round 1), Marcoo (Round 2) and Breakaway (Round 4), blast gauge sites were set out at distances corresponding to the anticipated pressure levels: 100, 72, 51, 37, 27, 20, 15, 11, 8.8, 6.8, 5.3, 4.3, 3.4, 2.7, 2.2, p.s.i. Two tube baffles were used at each site, plus one FMT gauge from 51 p.s.i. downwards and one diaphragm gauge from 37 p.s.i. downwards.

For Round 3, the air drop at Kite, a similar arrangement had been planned but included extra forward gauge sites to allow for inaccuracy of drop. Owing to a late change in the weapon to be dropped the gauge sites for Kite were altered at Maralinga, some of the existing sites being used and some new ones prepared. On this Round also, the baffles were mounted horizontally.

A schedule of sites is set out in Tables 2 to 4 (pp. 11 and 13).

As previously indicated, the drag gauges were used on Rounds 1, 3 and 4 and were mounted in pairs on heavy girders (Figure 3). A schedule of sites is set out in Table 5 (p. 14).

4. Results

4.1 Pressure Data, Including Duration of Positive Phase and Time of Arrival of Shock Front

A very high percentage of records was obtained and recovered, yielding extremely good results.

The pressure data are set out in Tables 2 to 4. On Rounds 1, 3 and 4 a precursor was developed, giving rise to irregular multipeaked wave shapes above a certain pressure level. Where this happened the letter "P" is written against the quoted "peak pressure" in the table and the actual FMT record is reproduced later in the report. To illustrate the smooth FMT records, other Figures, e.g., 9, 10, 15, 16, 18 and 24, show the records from sites beyond the precursor region. Where the actual record has not been reproduced the wave shape was a single peak as in Figure 18.

The wave shapes from the diaphragm gauge resembled those of the FMT gauge in general form only; the details were lacking. But the results from the diaphragm gauges indicated that the precursor may have persisted to a slightly lower pressure than that indicated by the FMT gauges.

In the precursor region results from the collapsible tubes were very erratic, as might be expected. The results from the tubes on Round 1 were markedly lower than those obtained from the FMT or diaphragm gauges; no explanation can be seen for this.

The results are also set out in 16 graphs, Figures 25 to 40. These are for each round:-

(a) Pressure/distance curve based on the FMT results.

(b) Pressure/distance curve for diaphragm gauge and tube results showing fit to FMT curve. Only points outside the precursor region have been plotted. Reference to the table shows the irregularity of mechanical gauge results within the precursor region.

(c) Duration/distance curve based on FMT results.

(d) Time of arrival/distance curve based on FMT results.

For Rounds 1 and 4 the pressure/distance curves were fitted to give the best agreement with the AWRE "Height of Burst" data (see Figure 41). An approximate yield figure was obtained by inspection, and the equation to the pressure/distance curve was calculated from the "Height of Burst" data and fitted to the Buffalo results by choice of a suitable scaling factor to give the best "least squares" fit.

For Rounds 1, 3 and 4, the points on the pressure/distance curve are joined by a firm line only where the shape of the pressure pulse was normal.

4.2 Drag Gauge Results

5 The drag gauge results are given in Table 5 (p. 14). No results are shown for the front piston of the gauge because in no case was any significant thrust from the sand particles recorded. No significant quantity of sand was collected inside the gauges either.

5. Conclusions

5.1 Pressure Measurements - Weapon Yields

From the pressure/distance data estimates were made of the TNT charge which, fired in the same conditions, would give the same pressure/distance relationship; this was done by comparing the results with the British "Height of Burst" curves (Figure 41) which are drawn from pressure measurements in small charge firings.

The equations fitted to the pressure/distance data were of the form:-

$$P = \frac{as}{R} + \frac{bs^2}{R^2} + \frac{cs^3}{R^3}$$

P being peak pressure and R being distance. The constants a, b and c were derived from the height of burst curves and s was fitted by least squares.

To convert the equivalent TNT charge to "Total Energy" it is necessary to know what fraction of the total energy goes into blast. The figure usually accepted is 0.45 but this is believed to be applicable strictly to free air conditions. To use the 0.45 factor to estimate Buffalo yields, it must be assumed that the partition of energy is unaffected by the ground: this is probably nearly valid for Rounds 1, 3 and 4. For Round 2, however, which was burst actually on the ground, the 0.45 factor might well be in error.

The equivalent TNT charge was calculated separately for each type of gauge and the results were combined, with most weight being given to the FMT results, to give the values for yield quoted below in Table 1.

TABLE 1

Round No.	Equivalent TNT Charge, Thousands of Tons	Total Energy Output, kiloton
1	7.7	17
2	0.46	1
3	1.2	$2\frac{1}{2}$
4	6.75	15

In Table 6 (p. 14), the separate results for each type of gauge are shown with the yield figure again quoted on the basis that 1 kiloton total energy is equivalent in blast effect to 450 tons of TNT.

5.2 Drag Measurements - Commentary on Results

The results indicate that at some points higher stagnation pressures occurred than one would theoretically expect from the local hydrostatic pressure. These results were confirmed by the damage to the girders which supported the gauges, the middle girder on Round 1 being more severely damaged than the one in front of it which was 200 ft nearer Ground Zero. Similarly, the damage to the girder at 1200 ft on Round 3 was more than expected and consistent with the higher pressure recorded. The increase in stagnation pressure may have been caused by a local increase in air density. It was possible that the very fine dust in the area became dispersed in the air in such a finely divided state as to constitute a new fluid with a density approximately twice that of air.

It had been hoped to get more drag gauge data, the intention being to obtain a few results from Round 4 and put the main effort into the air drop weapon, Round 3. The latter, however, was reduced in yield to a point where it was valueless for drag measurements without extensive field engineering to extricate and reposition the girder gauge supports. In an attempt to obtain measurements, three girders were set up on Round 1 at short notice by scientific staff. It is gratifying that the results on Round 1 have proved the most interesting of those obtained.

5.3 Precursor Formation

The quality of the FMT records was such as to give a much clearer picture than before of the pressure/time variations in a precursor region. In particular it can be seen, by comparing the records from Rounds 1 and 4 with those from Round 3, that there are degrees of precursor formation. On Rounds 1 and 4 the multipeaked portion of the record is always preceded by a shock front. This is not so on Round 3. A more detailed examination of wave shape in the precursor region will be reported later when a comparison has been made with the shock front photographs obtained by the Canadian rocket trail team.

TABLE 2

Tower Bursts: Rounds 1 and 4

Table 2a: Round 1

Air temperature 22°C. Barometric pressure 998 mb.
Relative humidity 18%. P = precursor (see Section 4.1, para. 2).

Site	Distance, ft	Pressure, p.s.i.		
		FMT Gauges	Diaphragms	Tubes
AG 101	910			56
AG 103	1030			25
AG 104	1170	36.0 P		20.5
AG 106	1346	27.1 P	28.0 P	7.6
AG 108	1520	22.7 P	14.0 P	3.6
AG 109	1730	20.4 P	15.0 P	6.7
AG 111	1960	15.0 P	15.0 P	10.8
AG 112	2140	13.5	12.5 P	11.0
AG 114	2540	9.76	9.05	7.3
AG 115	2920	7.32	7.20	5.6
AG 117	3330	5.64	5.85	5.1
AG 118	3780	4.65	4.50	4.15
AG 121	4300	3.38	3.85	3.4
AG 123	4860	3.07	3.05	2.5
AG 124	5550	2.61	3.05	2.3

Table 2b: Round 4

Air temperature 13.1°C. Relative humidity 84%.

Barometric pressure 993.9 mb. P = precursor (see Section 4.1, Para.2).

Site	Distance, ft	Pressure, p.s.i.		
		FMT Gauges	Diaphragms	Tubes
AG 301	780	-		-
AG 302	880	-		-
AG 303	1000	-		24.7
AG 304	1140	31.9 P		7.1
AG 306	1290	28.1 P		5.5
AG 308	1480	24.4 P	32.7 P	5.5
AG 310	1680	17.8 P	20.2 P	7.9
AG 311	1920	14.2	13.7 P	11.8
AG 312	2180	11.6	11.00	11.1
AG 313	2500	8.88	9.05	8.6
AG 314	2800	7.30	7.50	7.1
AG 315	3230	5.58	5.90	5.7
AG 316	3680	4.47	4.60	4.0
AG 318	4160	4.00	3.85	3.6
AG 319	4740		3.20	3.0

TABLE 3

Ground Burst: Round 2

Air temperature 22.6°C. Relative humidity, 35%.

Barometric Pressure 992 mb.

Site	Distance, ft	Pressure, p.s.i.		
		FMT Gauges	Diaphragms	Tubes
AG 206	410			45.3
AG 208	470			32.3
AG 209	530	37.0		21.1
AG 211	610	26.0	22.50	27.0
AG 212	690	19.3	18.00	18.00
AG 214	780	15.1	12.70	12.70

TABLE 3 (Contd.)

Site	Distance, ft	Pressure, p.s.i.		
		FMT Gauges	Diaphragms	Tubes
AG 215	870	12.3	10.05	12.1
AG 217	1020	9.30	8.20	9.9
AG 219	1160	7.03	6.80	7.3
AG 220	1330	5.88	5.80	5.6
AG 222	1510	4.80	4.80	4.9
AG 223	1720	3.96	4.05	4.3
AG 225	1960	3.26	3.40	3.4
AG 226		2.67	2.95	2.5
AG 228		2.35	2.45	2.3

TABLE 4

Air Drop: Round 3

Air temperature 24.1°C.
Relative humidity, 35%.

Barometric pressure 998 mb.
P = precursor (see Section 4.1, para. 2).

Site	Distance, ft	Pressure, p.s.i.		
		FMT Gauges	Diaphragms	Tubes
AG 401	-			
AG 402	-			63*
AG 403	-			
AG 403/1	300			43.8
AG 403/2	420			35.8
AG 405	580	15.9 P		43.6
AG 405/1	740	24.7 P		3.7
AG 407	990	16.4 P		2.8
AG 408	1320	9.87 P		0
AG 411	1750	8.90	9.05	7.6
AG 414	2290	5.84	6.00	5.6
AG 416	2850	4.23	4.45	3.8
AG 419	3440	3.08	3.05	3.0
AG 422	3990	2.44	2.60	2.3

* Over 85 on remote site of Ground Zero.

TABLE 5

Drag Gauge Results

Round	Distance from Ground Zero, ft	Height of Gauge above Ground, ft	Peak Stagnation Pressure Recorded, p.s.i.	Theoretical Stagnation Pressure Based on FMT, p.s.i.
1	1358	$8\frac{1}{2}$ 3	38.6 46.2	46.5
	1545	$8\frac{1}{2}$ 3	52.0 80.0	34.0
	2171	$8\frac{1}{2}$ 3	16.8 15.0	17.0
4	1200	10 3	No result 83.0	70.0
	1400	10 3	48.5 64.0	40.0
	1600	10 3	8.5† 35	28.0
3	1200*	10 3	68 No result	29
	1800*	10	12.0	12

* Distance from Kite.
† Records went off paper.

TABLE 6

Buffalo Yield Results

Round	Gauge	Scale Factor to 1 kiloton Total Energy	Yield kiloton Total Energy
1	FMT Tubes Diaphragms	2.59 2.22 2.55	17.4 10.9 16.6
2	FMT Tubes Diaphragms	1.01 1.05 0.98	1.03 1.16 0.94
3	FMT Tubes Diaphragms	1.37 1.30 1.40	2.6 2.20 2.7
4	FMT Tubes Diaphragms	2.45 2.40 2.50	14.7 13.8 15.6

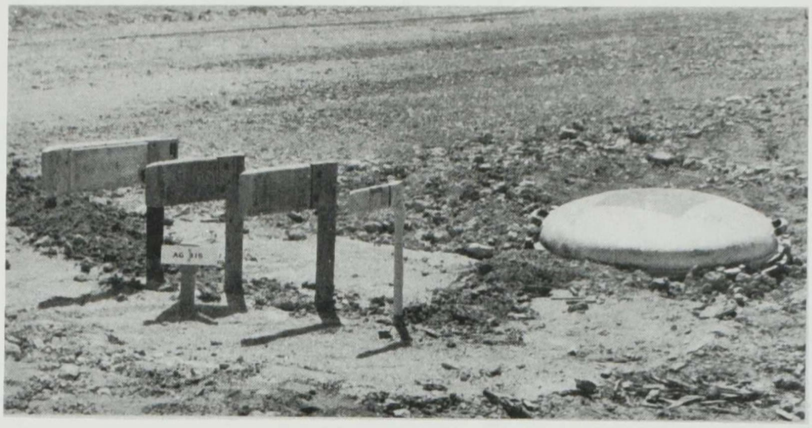

FIG. 1. BLAST GAUGE SITE, SHOWING (RIGHT TO LEFT) F.M.T. CONTAINER, F.M.T. GAUGE, TWO BAFFLES, & DIAPHRAGM GAUGE.

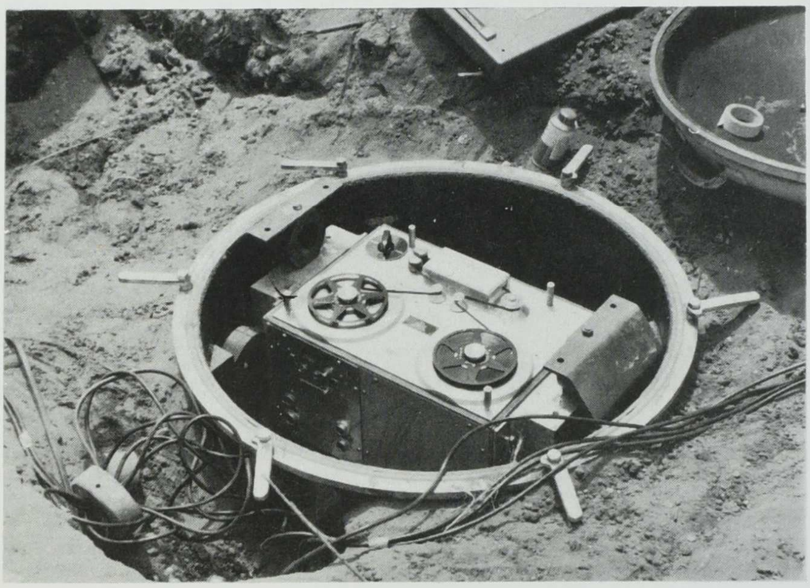

FIG. 2. F.M.T CONTAINER WITH LID REMOVED SHOWING TAPE DECK.

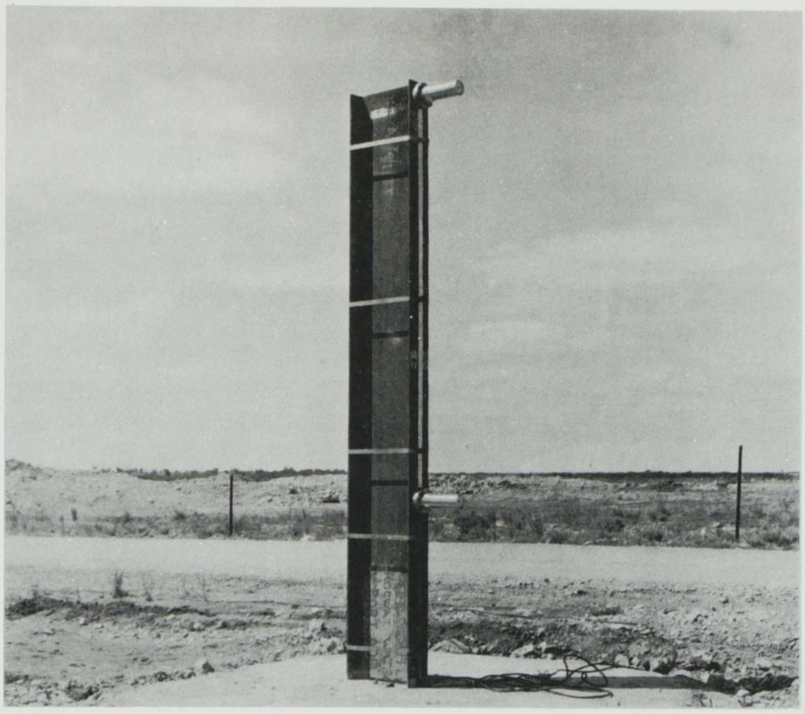

FIG. 3. DRAG GAUGES AT TWO HEIGHTS ON MAST.

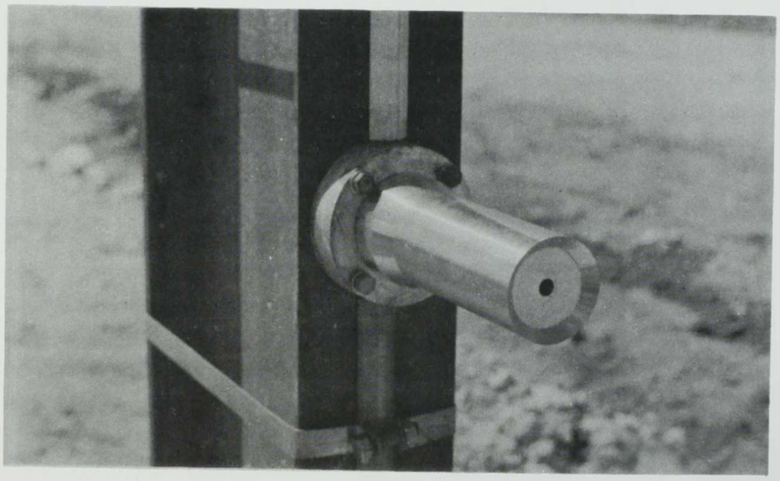

FIG. 4. DRAG GAUGE CLOSE-UP.

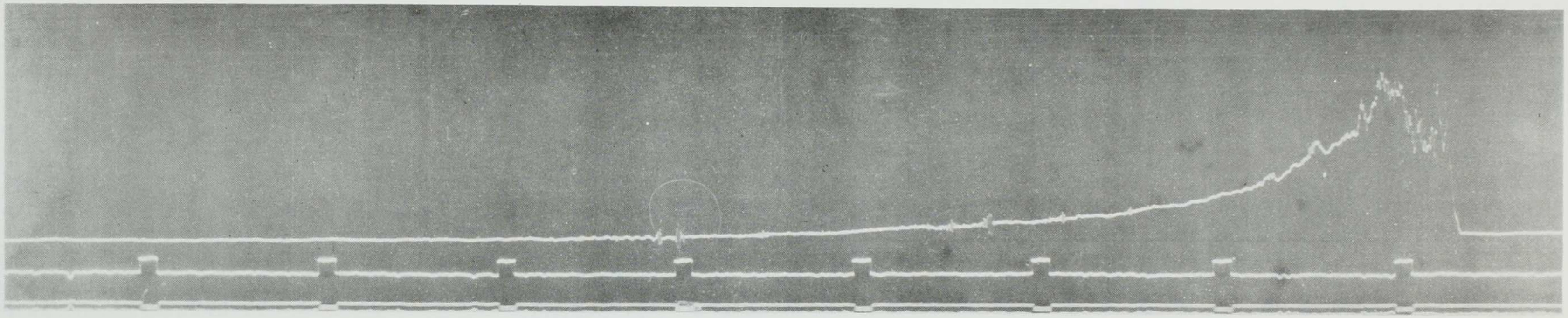

FIG. 5. AG 104 1170 FT. 36 P.S.I.

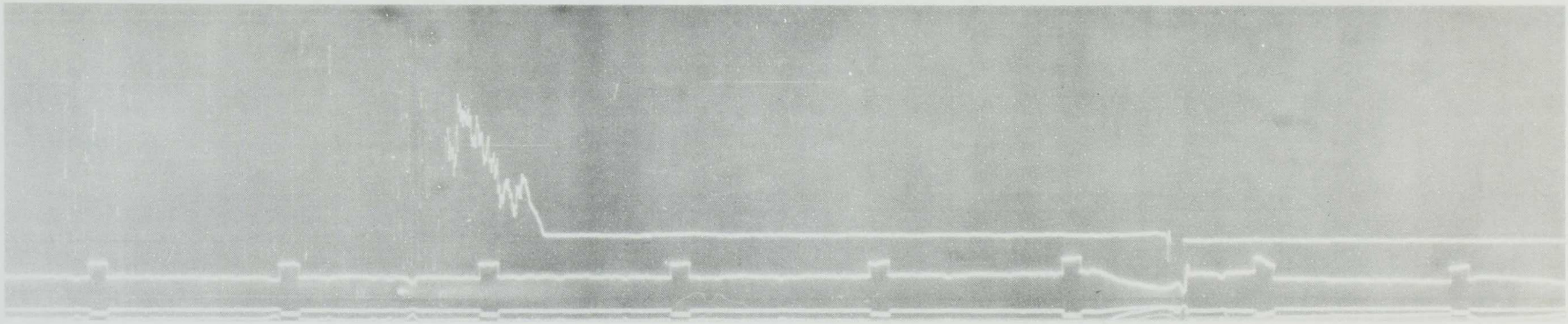

FIG. 6. AG 106 1350 FT. 27 P.S.I.

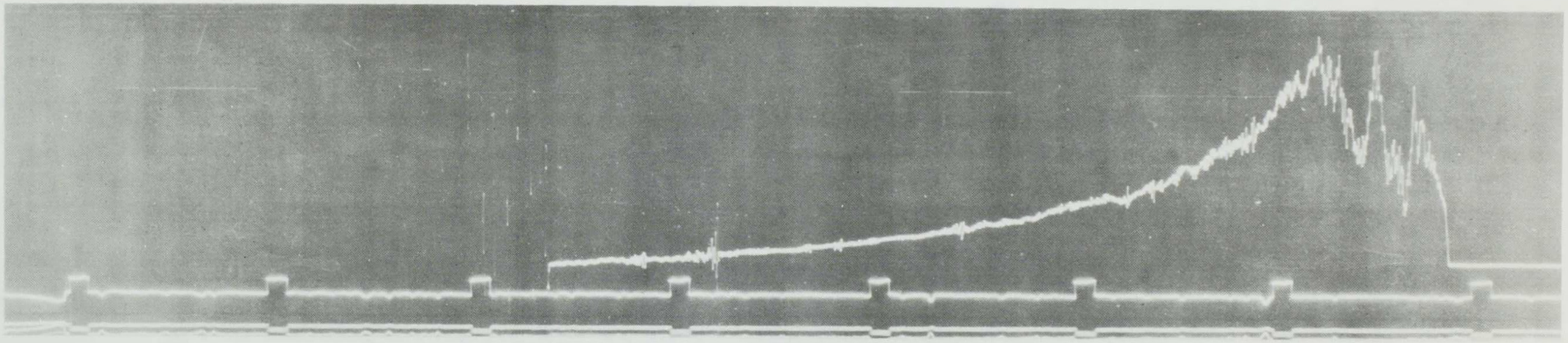

FIG. 7. AG 108 1520 FT. 22·7 P.S.I.

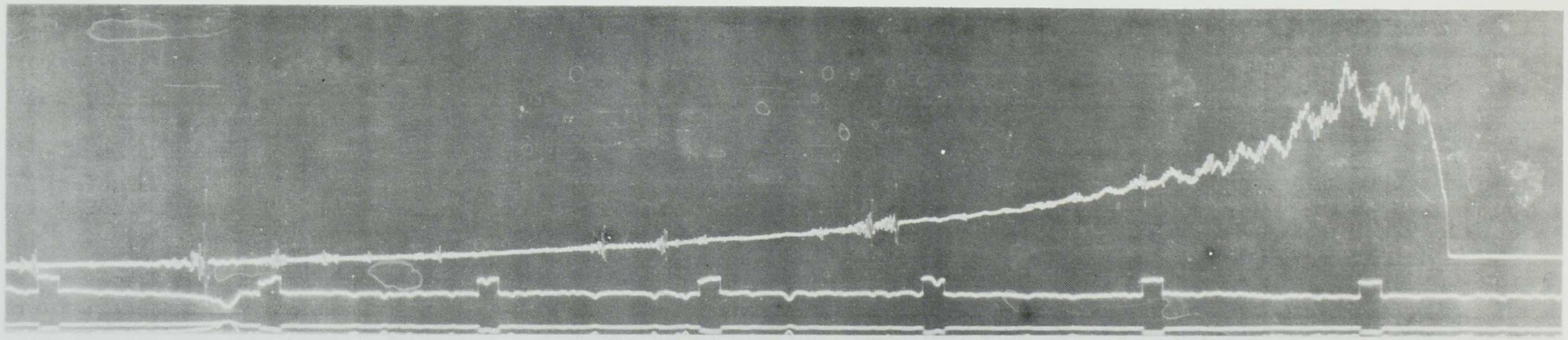

FIG. 8. AG 109 1730 FT. 20·4 P.S.I.

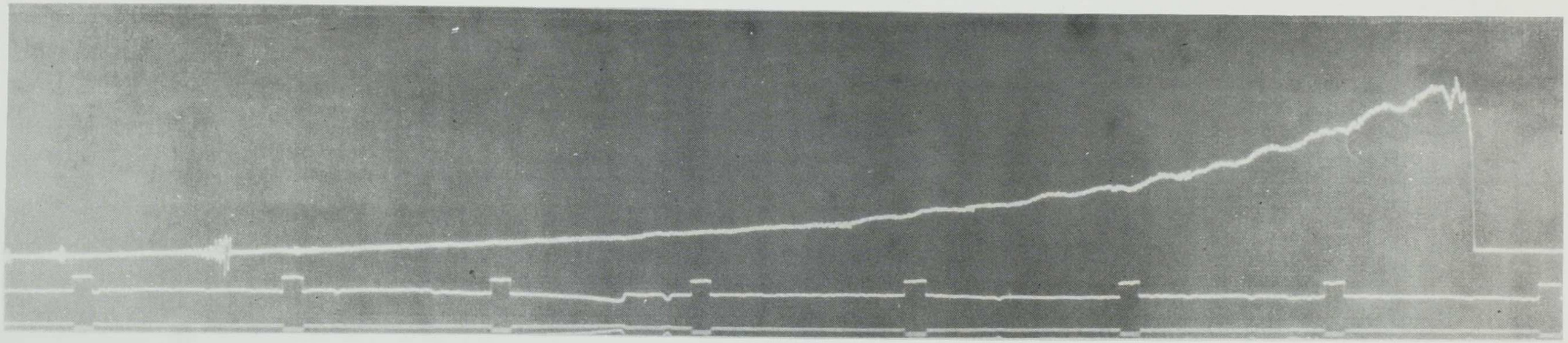

FIG. 9. AG 111 1960 FT. 15 P.S.I.

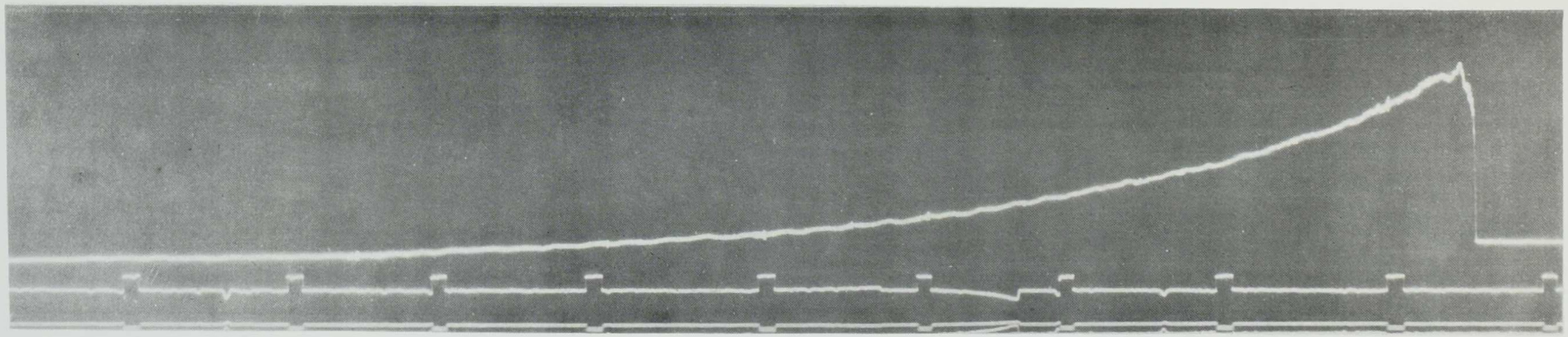

FIG. 10. AG 112 2140 FT. 13·5 P.S.I.

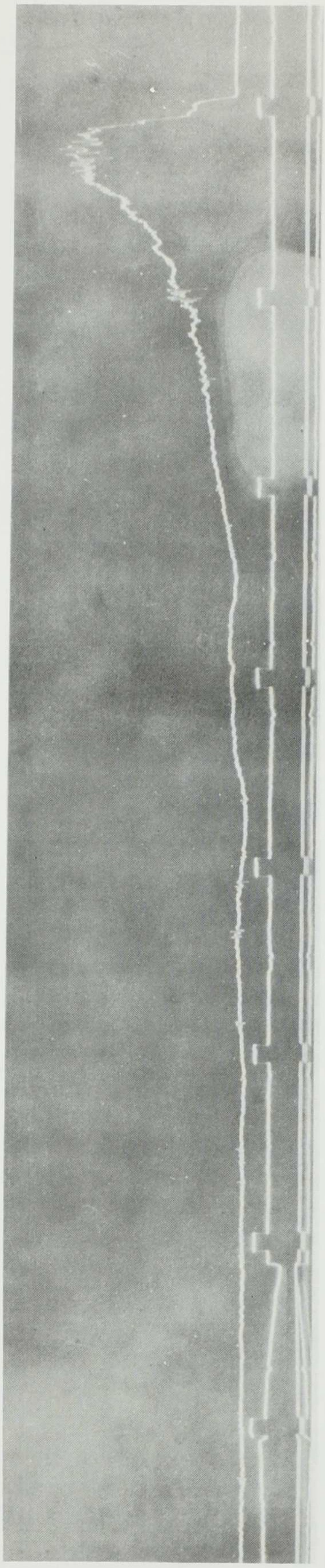

FIG. 11. AG 304 1140 FT. 32 P.S.I.

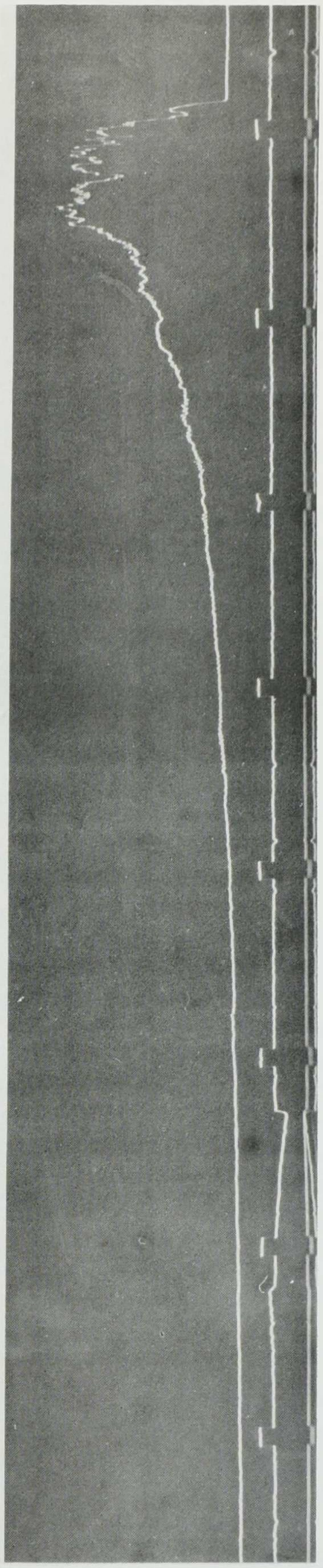

FIG. 12. AG 306 1290 FT. 28 P.S.I.

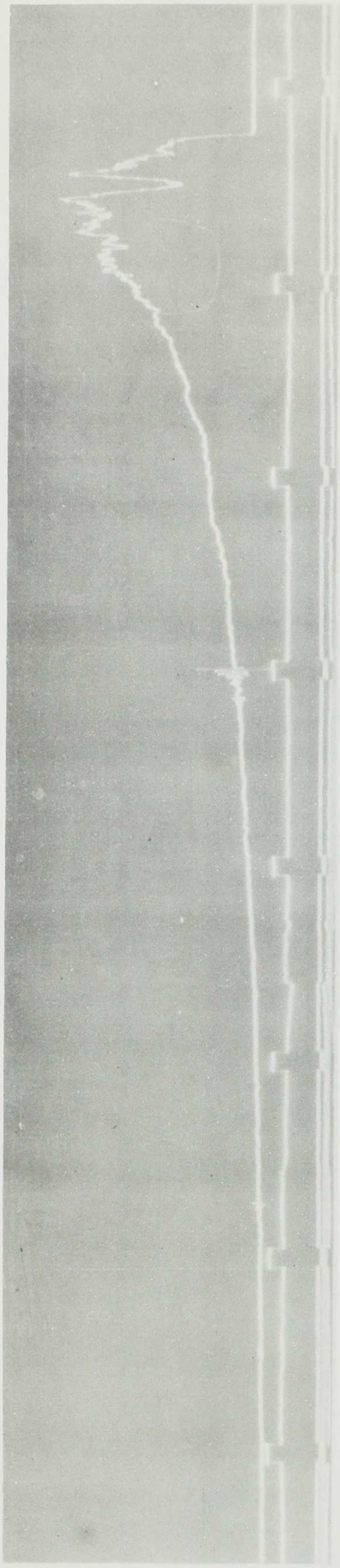

FIG. 13. AG 308 1480 FT. 24·4 P.S.I.

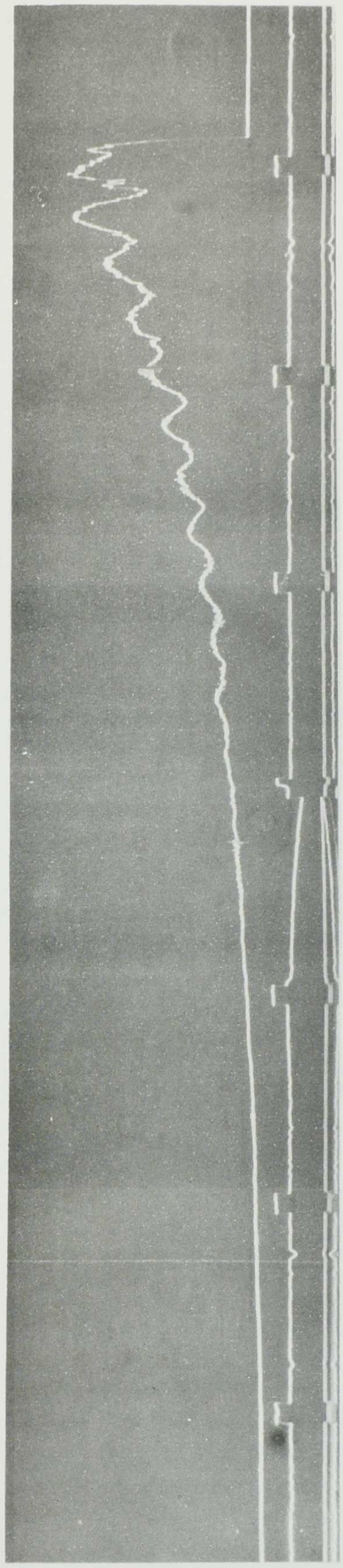

FIG. 14. AG 310 1680 FT. 17·8 P.S.I.

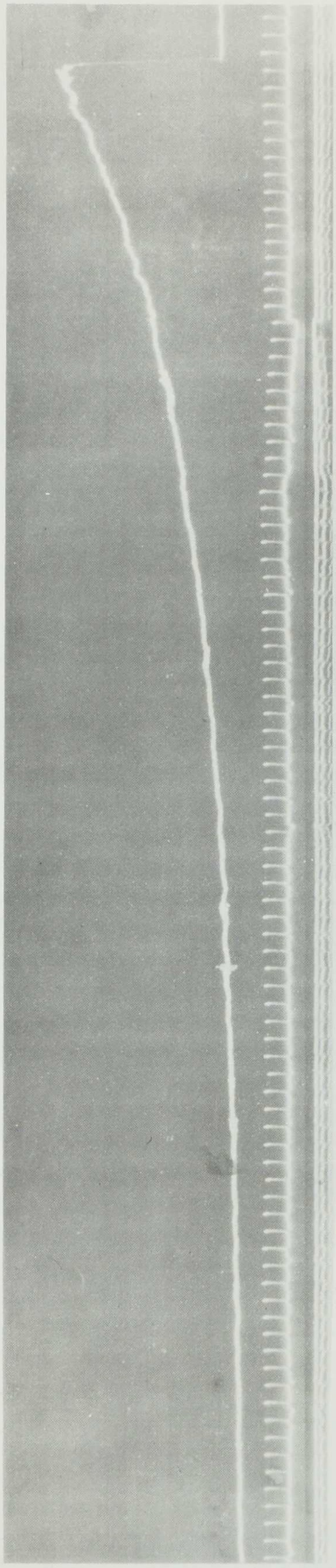

FIG. 15. AG 311 1920 FT. 14·2 P.S.I.

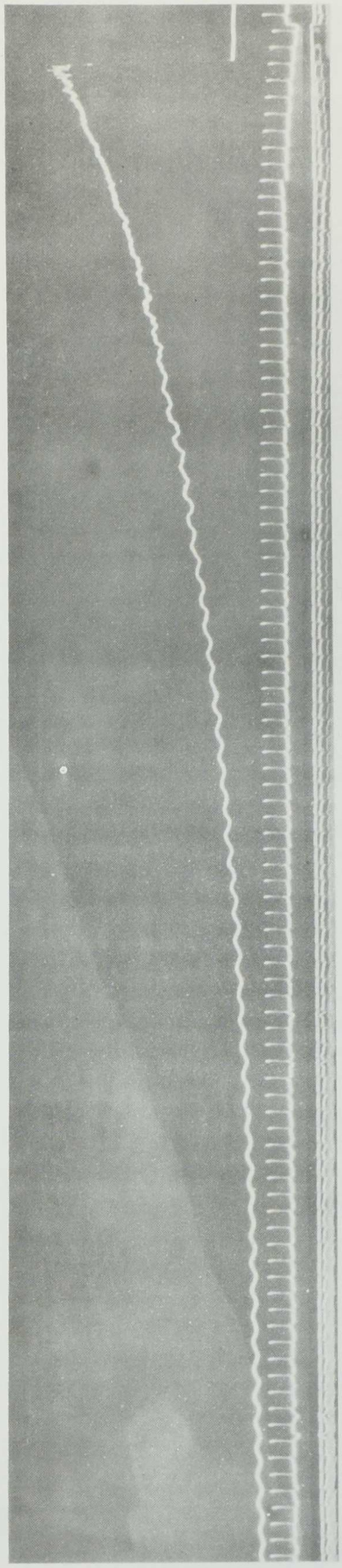

FIG. 16. AG 312 2180 FT. 11·6 P.S.I.

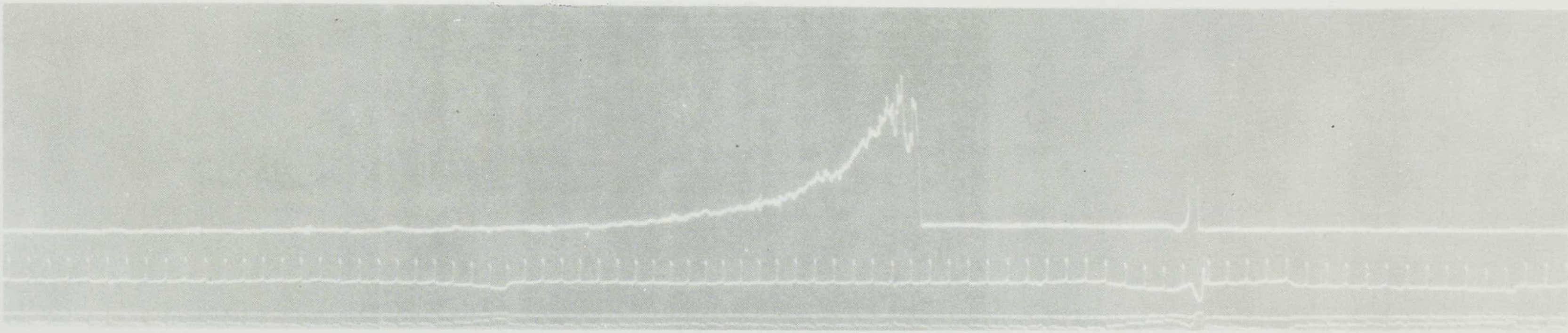

FIG. 17. AG 209 530 FT. 37 P.S.I.

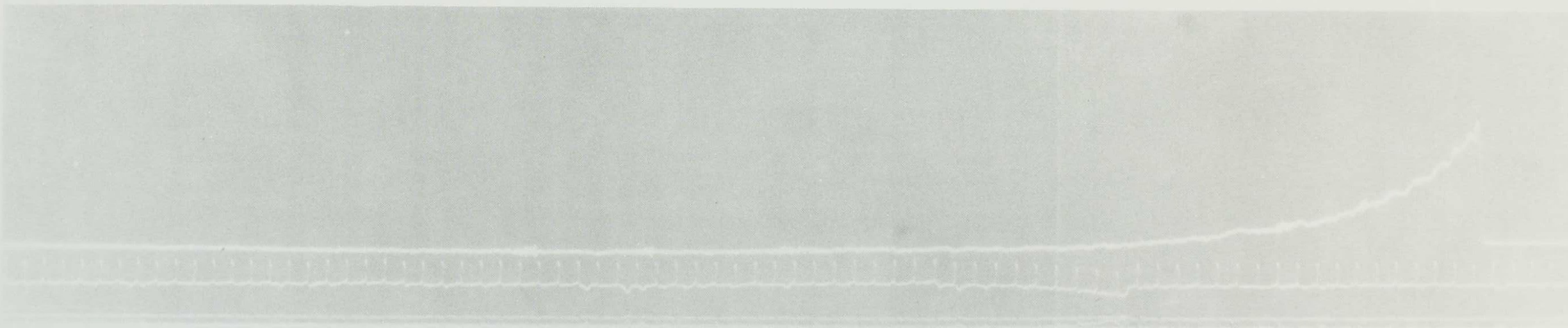

FIG. 18. AG 211 610 FT. 26 P.S.I.

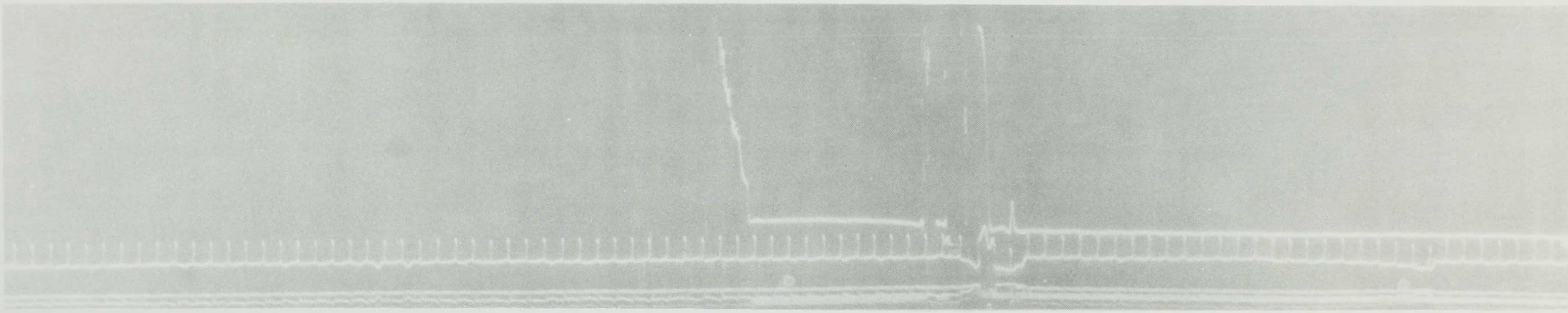

FIG. 19. AG 403/2 420 FT.

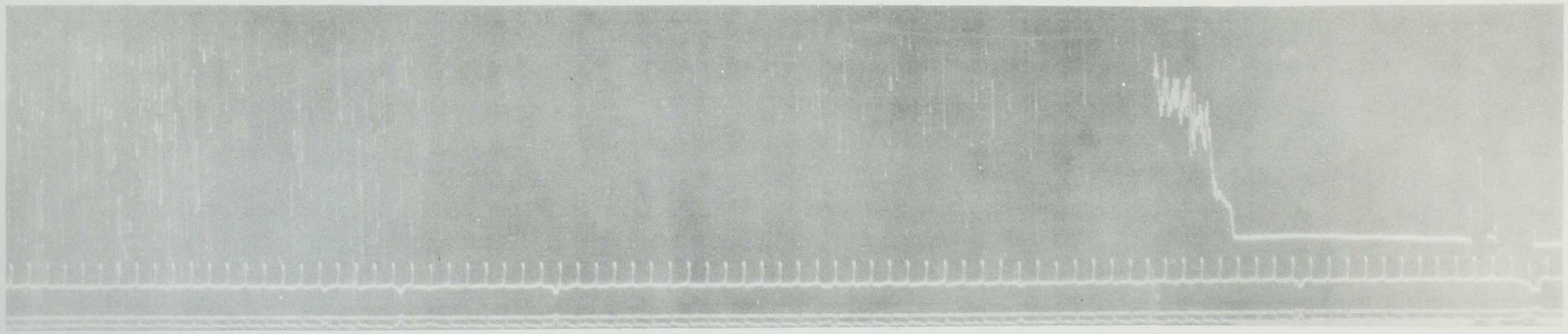

FIG. 20. AG 405 580 FT. 15·9 P.S.I.

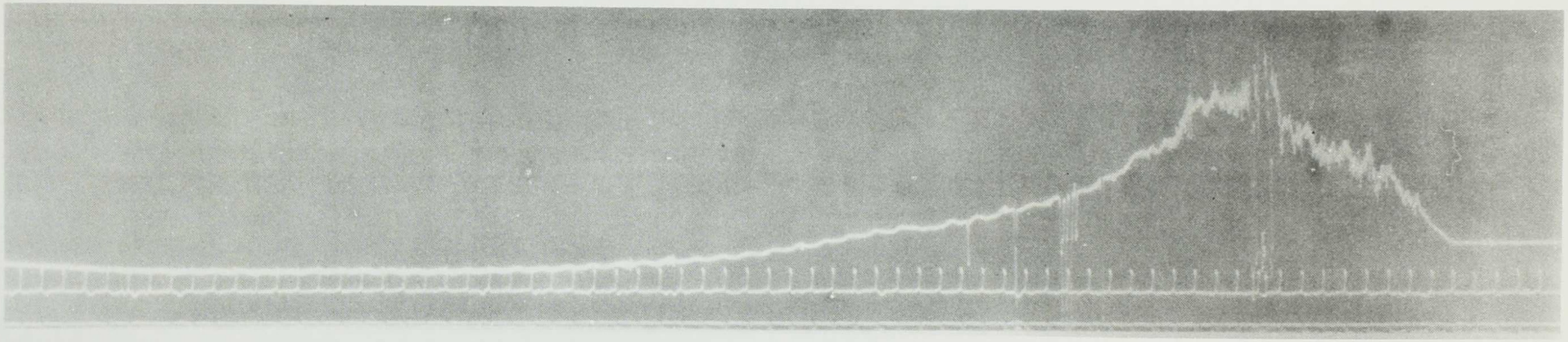

FIG. 21. AG 405/1 740 FT. 24·7 P.S.I.

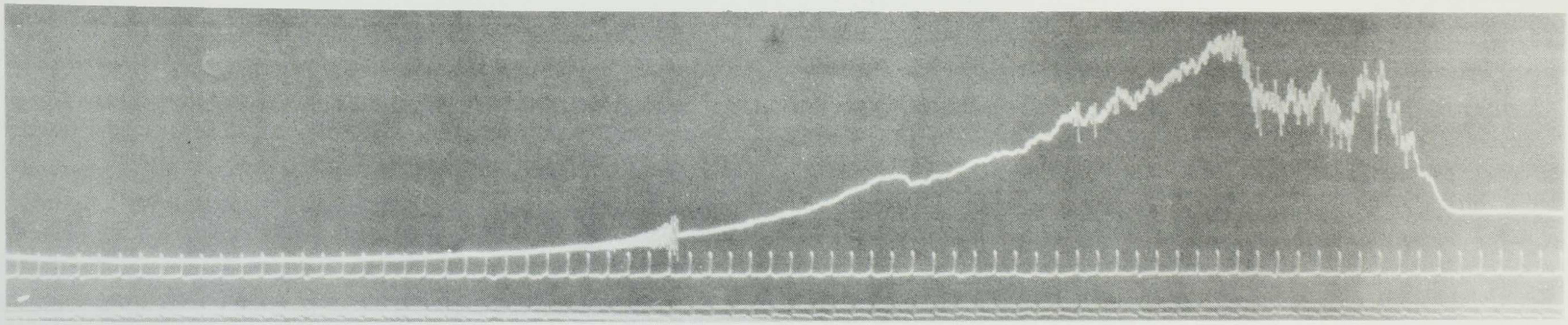

FIG. 22. AG 407 990 FT. 16·4 P.S.I.

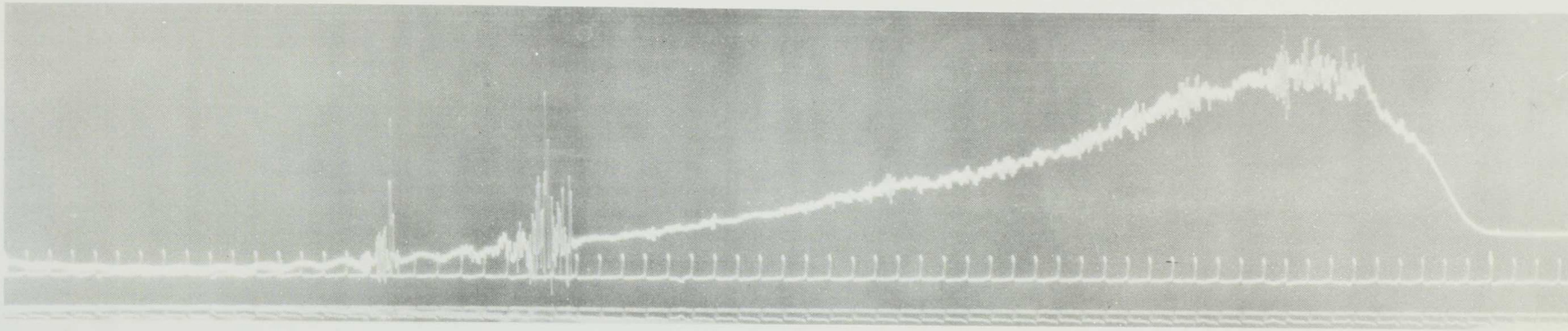

FIG. 23. AG 408 1320 FT. 9·9 P.S.I.

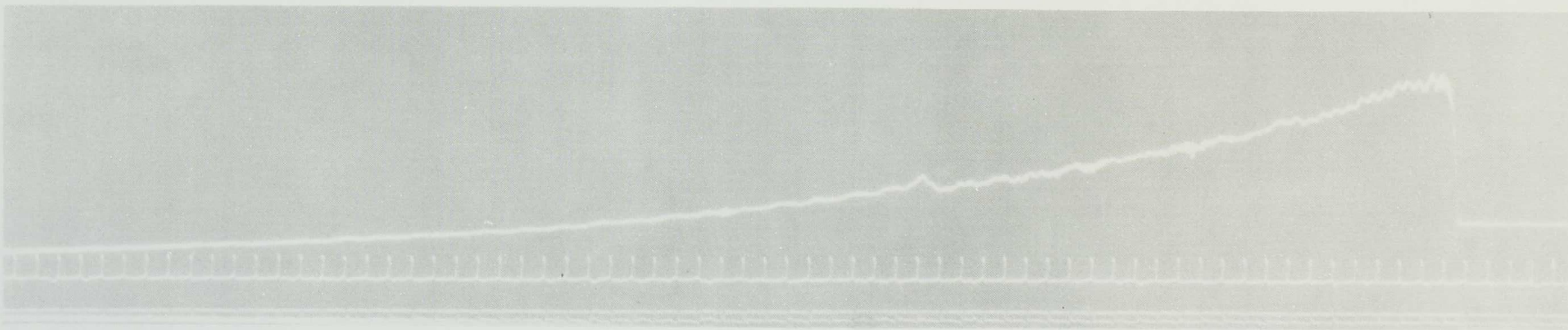

FIG. 24. AG 411 1750 FT. 8·9 P.S.I.

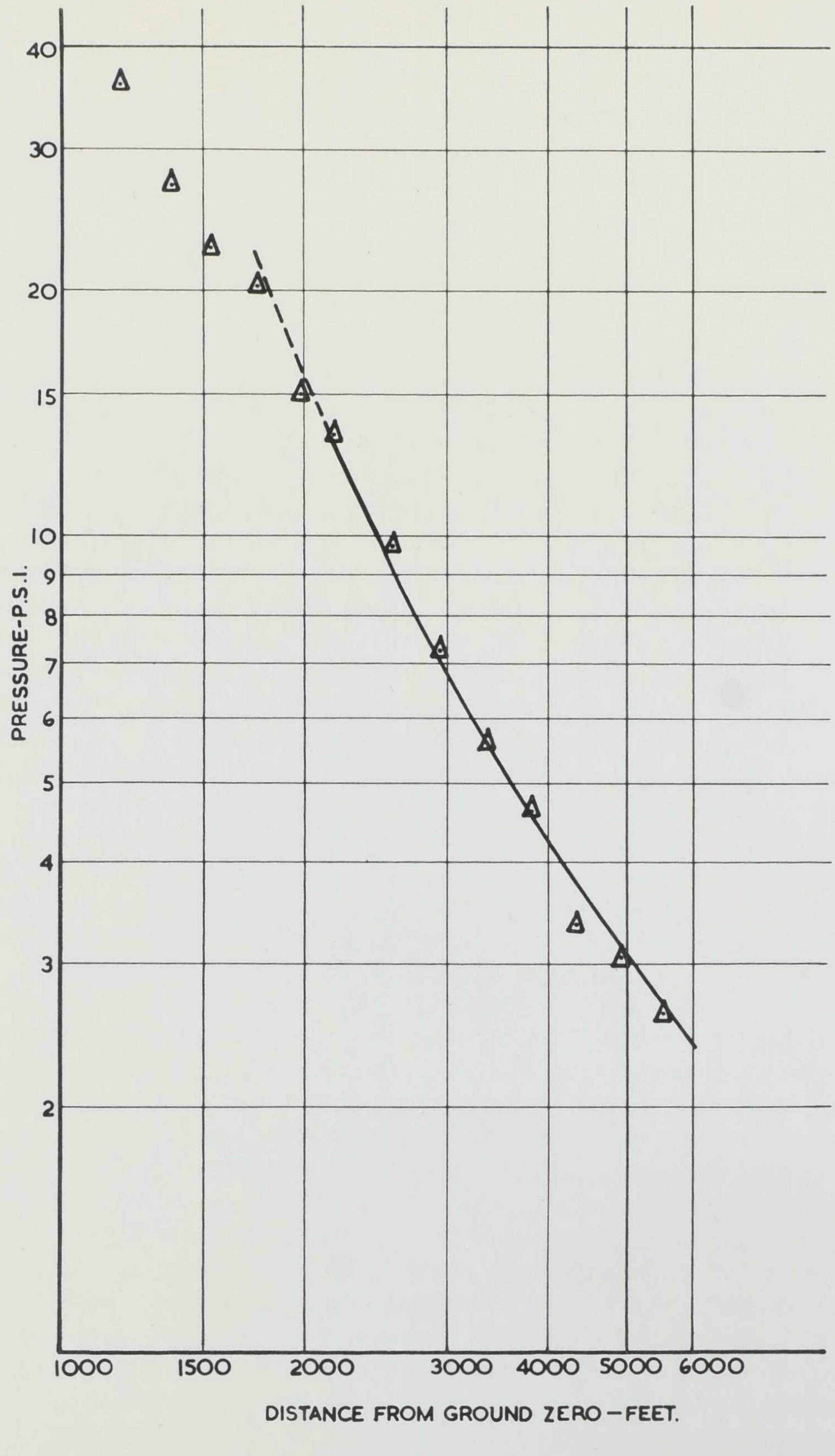

FIG.25. ROUND.1. – PRESSURE/DISTANCE CURVE. FMT. RESULTS.

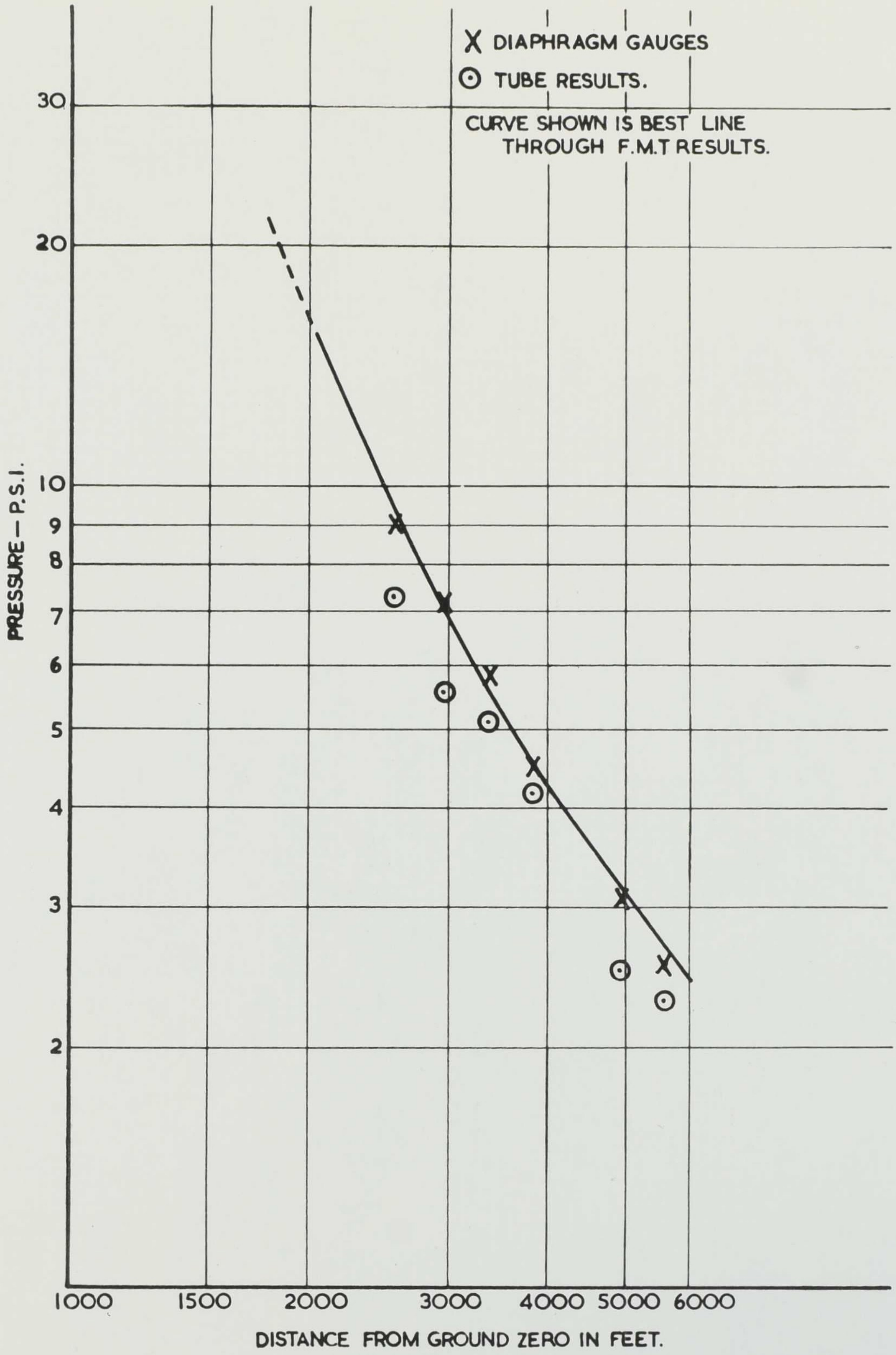

FIG. 26. ROUND. I.–PRESSURE / DISTANCE CURVE. DIAPHRAGM & TUBE RESULTS.

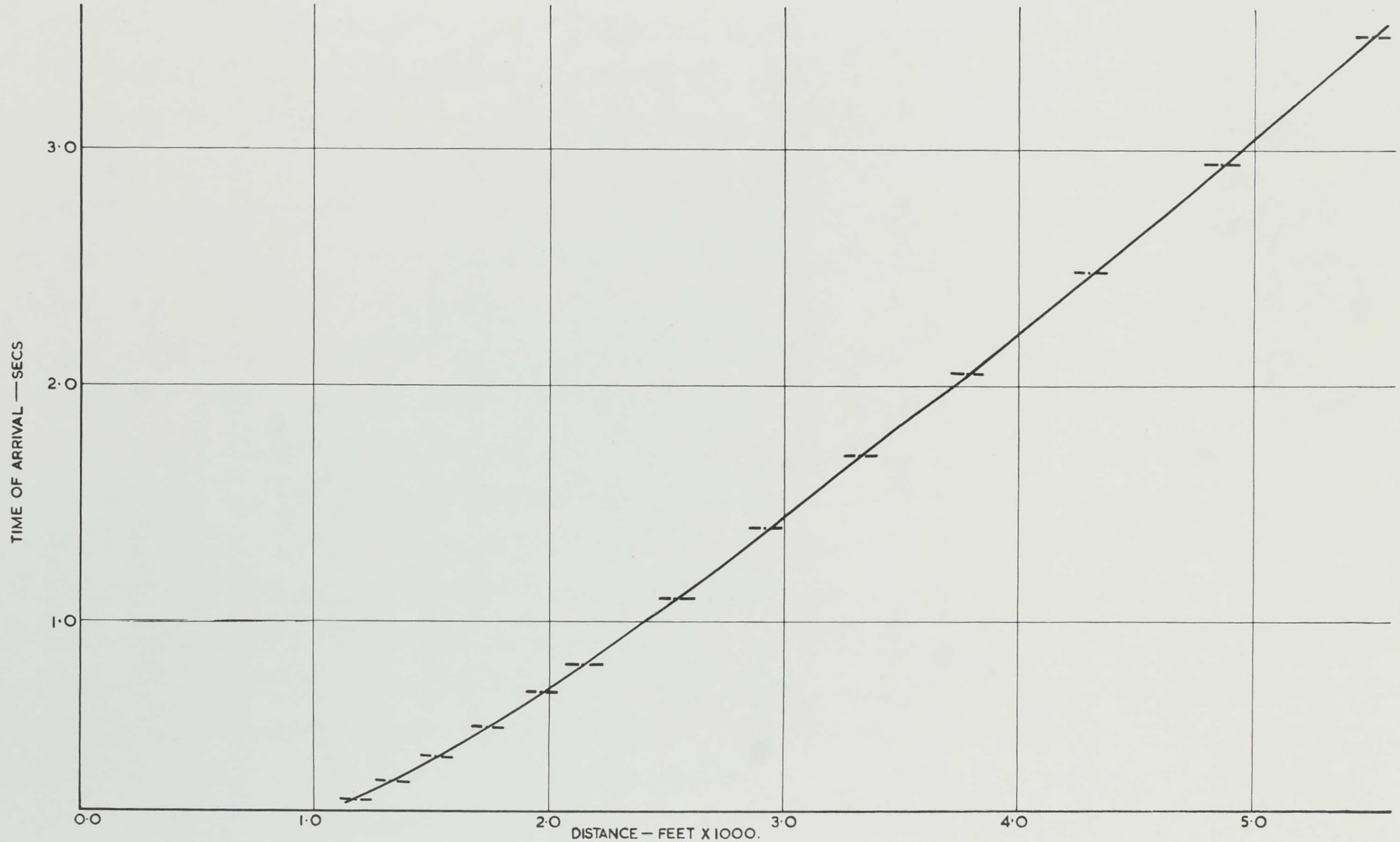

FIG. 27. ROUND.I.– DISTANCE/TIME CURVE.

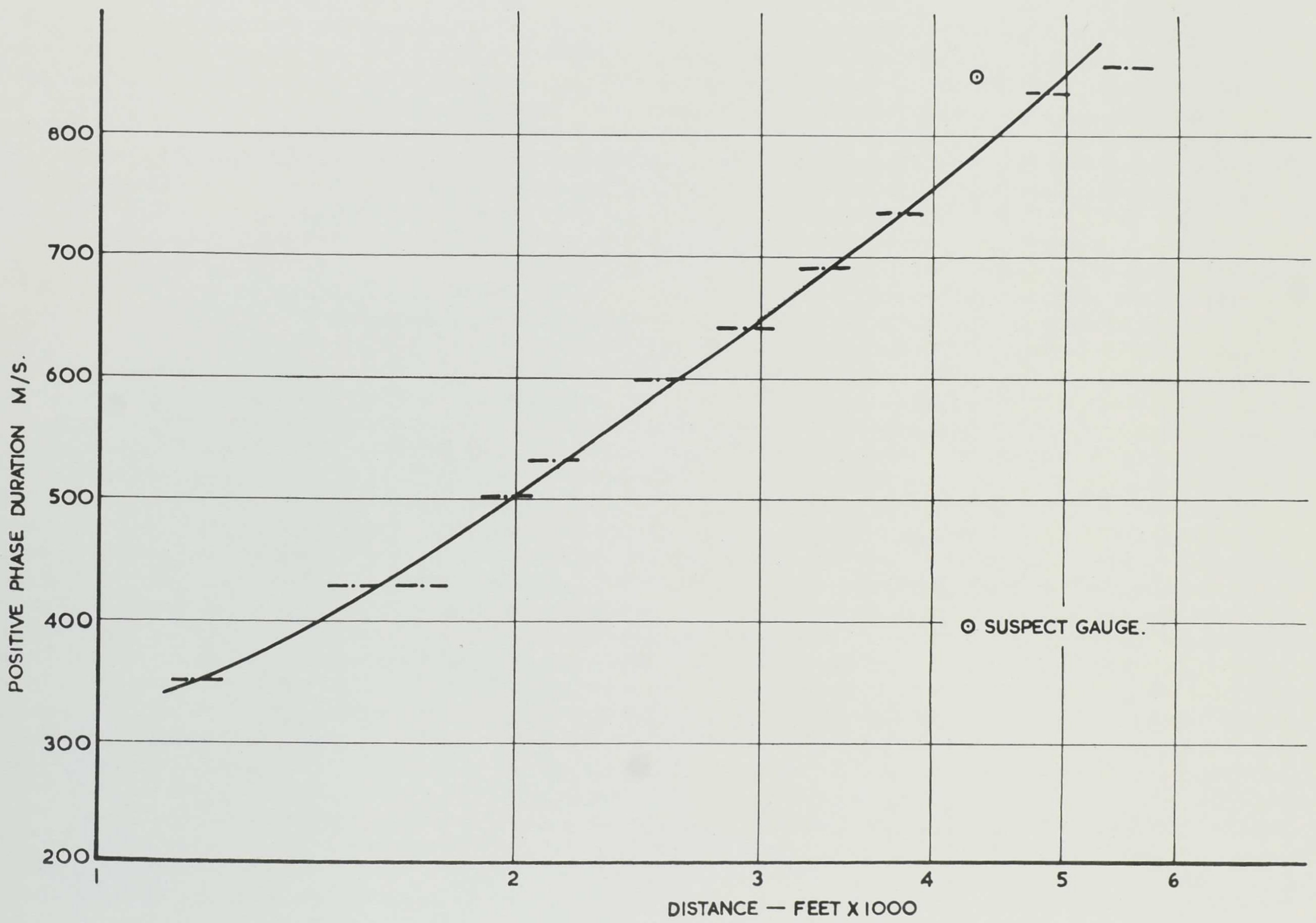

FIG. 28. ROUND.I. — DISTANCE/PHASE DURATION CURVE.

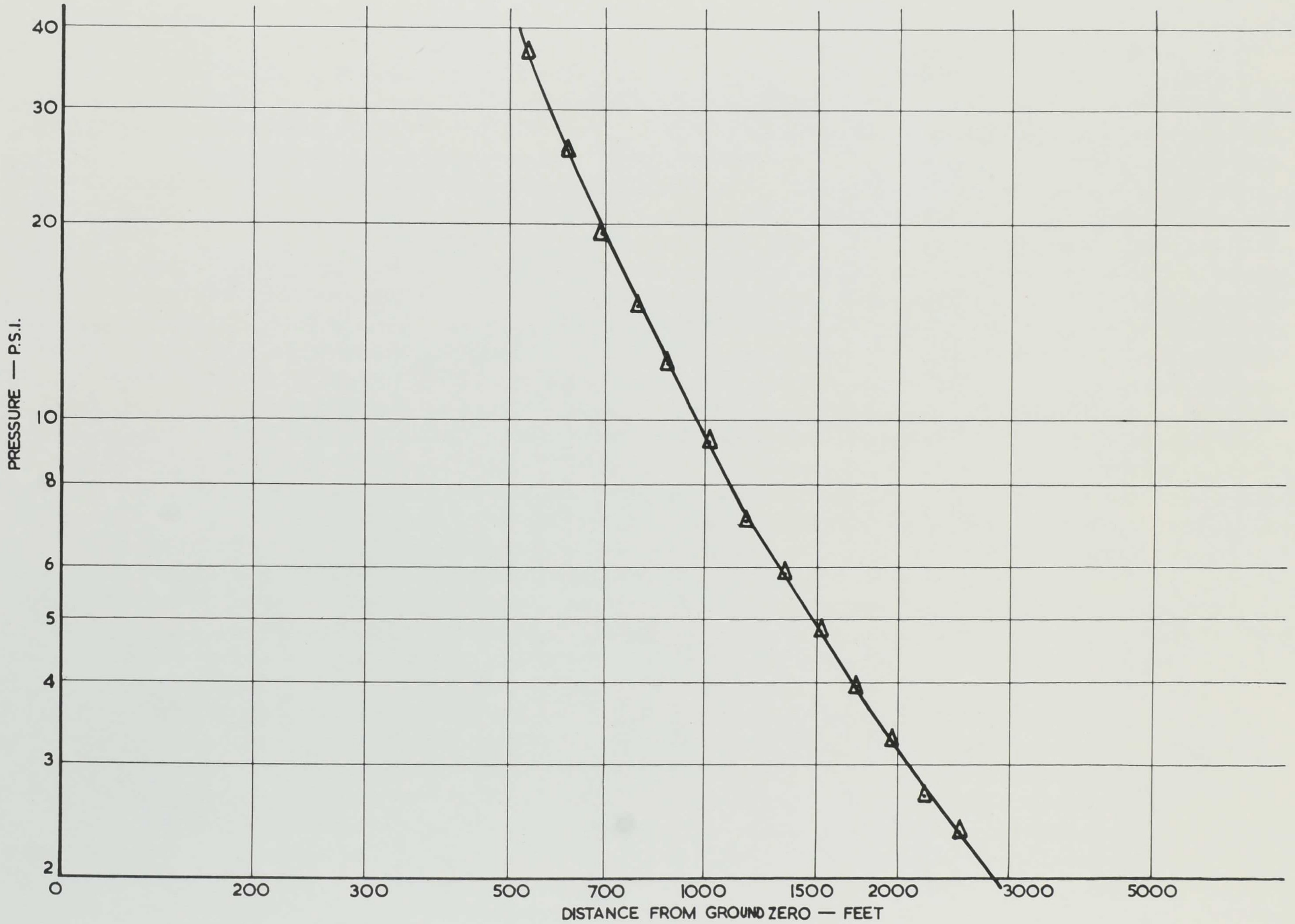

FIG. 29. ROUND 2. – PRESSURE/DISTANCE CURVE FMT RESULTS.

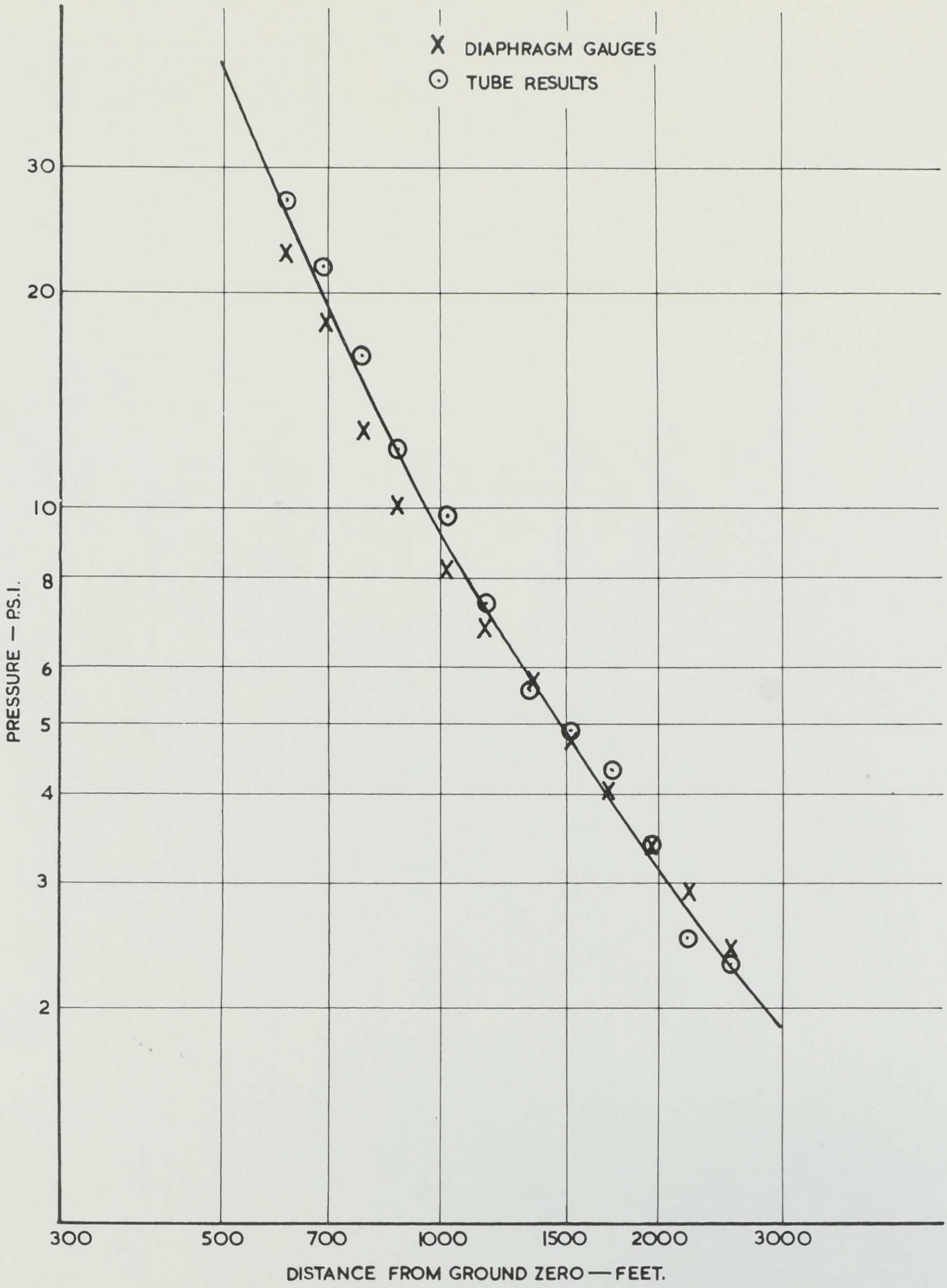

FIG. 30. ROUND 2. — PRESSURE / DISTANCE CURVE. DIAPHRAGM & TUBE RESULTS

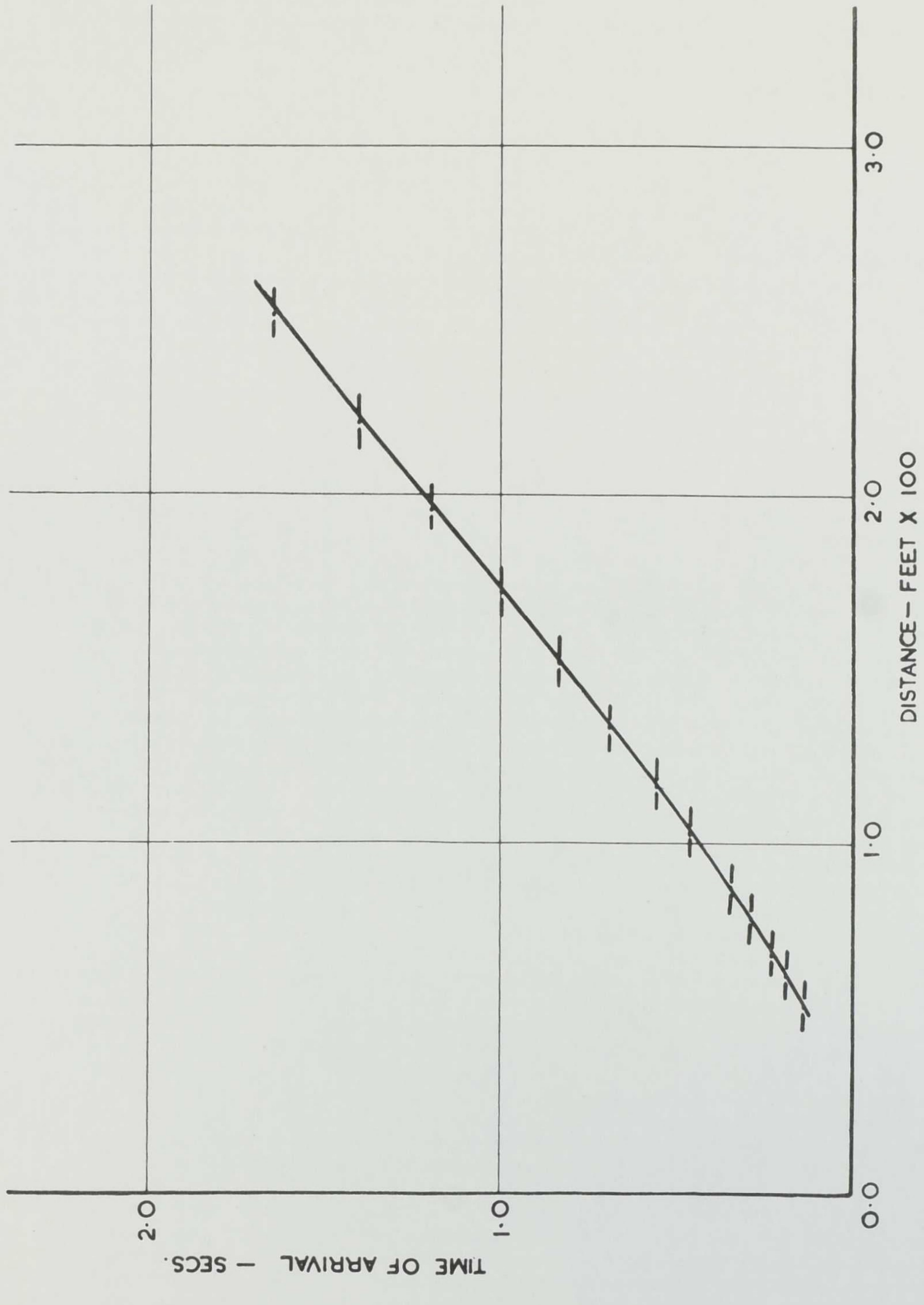

FIG. 31. ROUND 2. – DISTANCE / TIME CURVE.

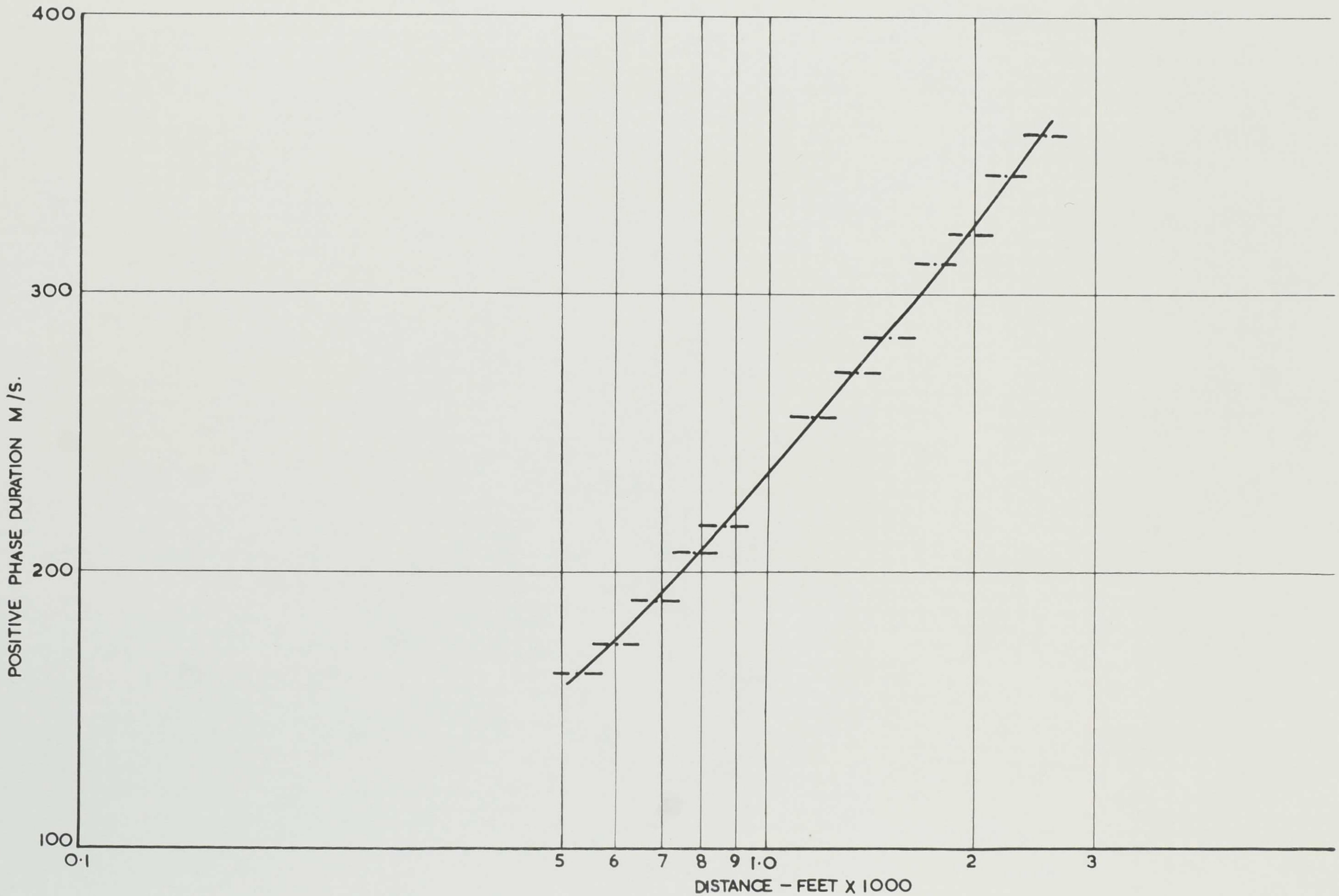

FIG. 32. ROUND 2. – DISTANCE/PHASE DURATION CURVE.

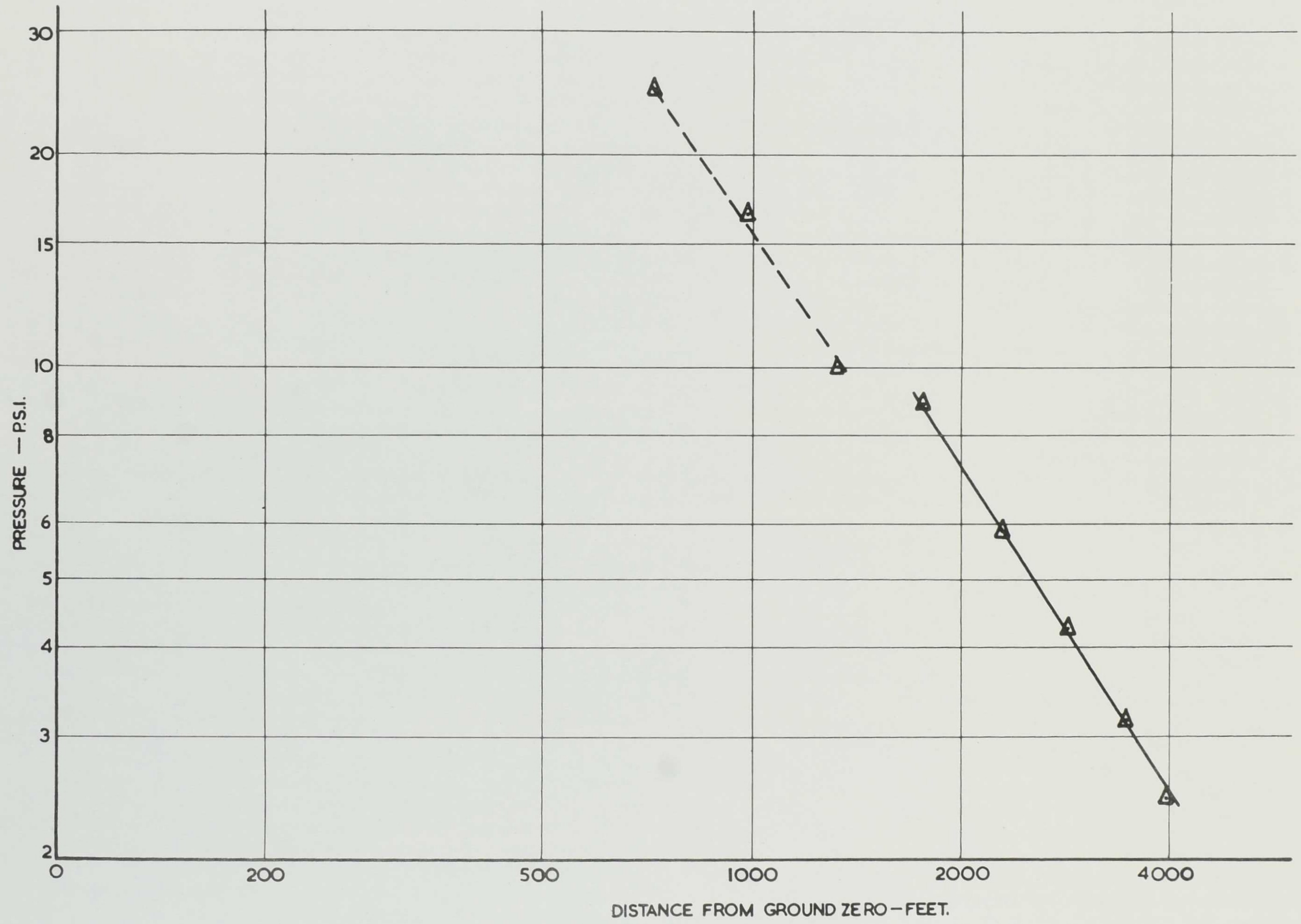

FIG. 33. ROUND 3.-PRESSURE/DISTANCE CURVES FMT RESULTS.

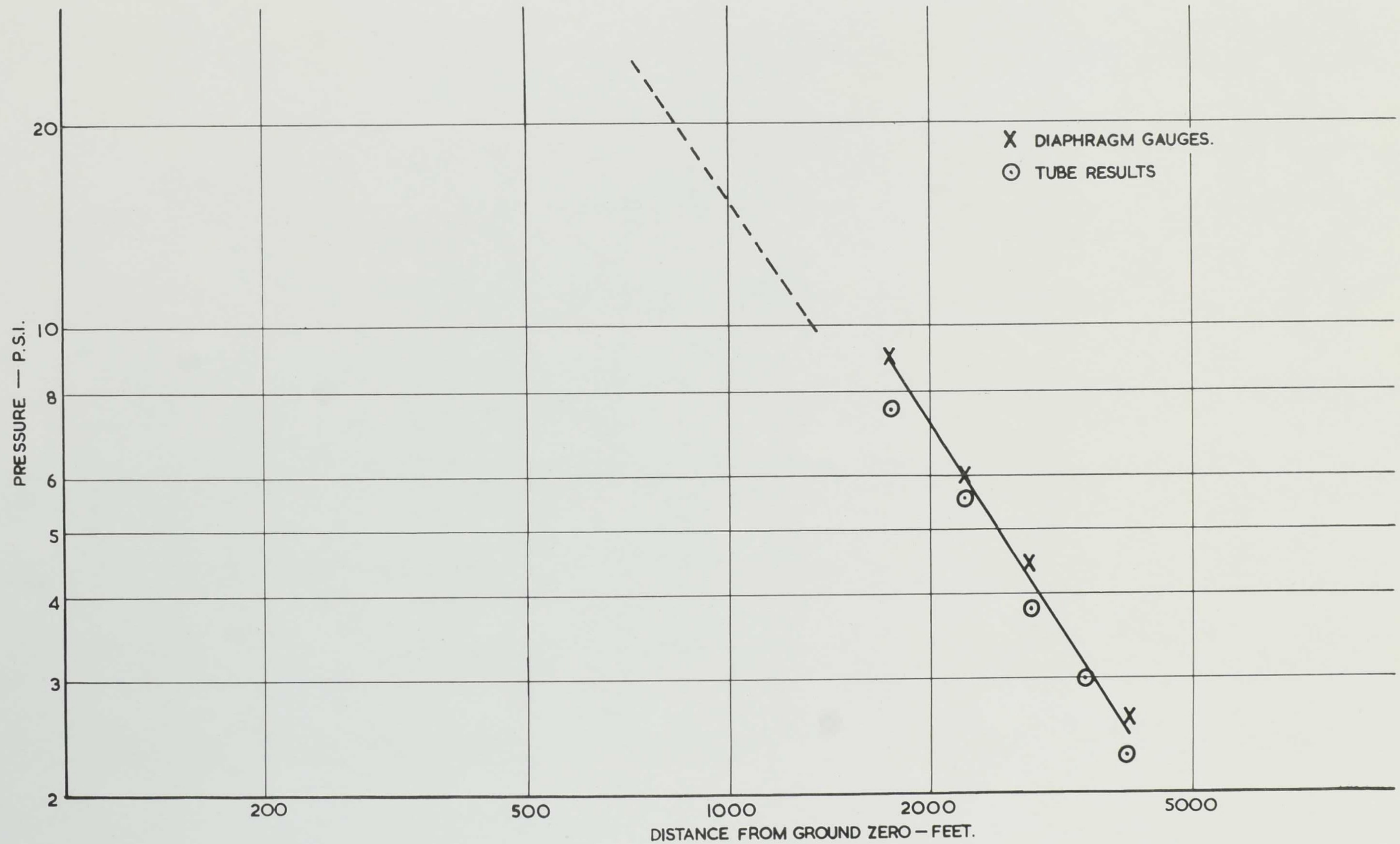

FIG. 34. ROUND 3. – PRESSURE / DISTANCE CURVES DIAPHRAGM & TUBE RESULTS.

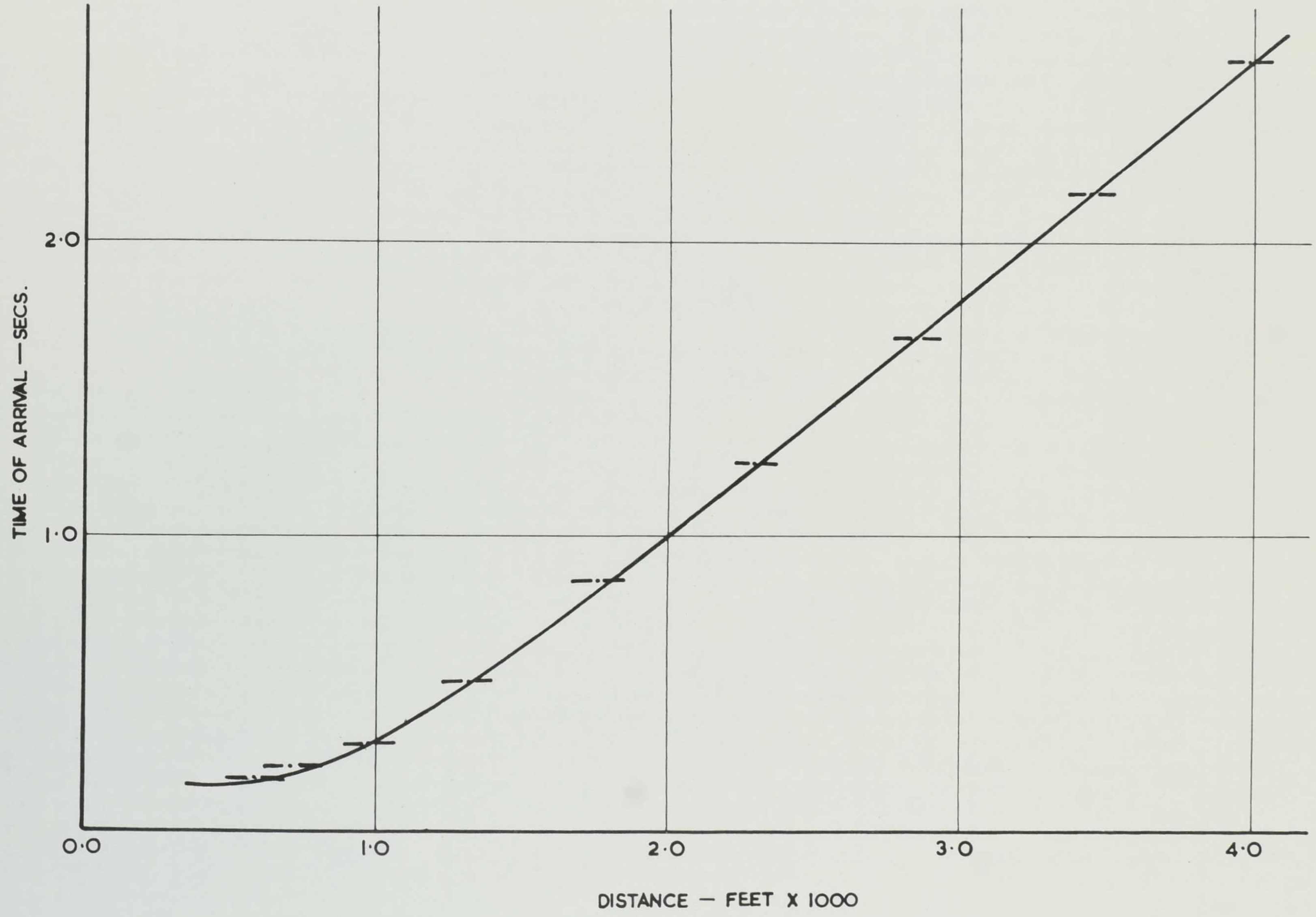

FIG. 35. ROUND 3.— DISTANCE / TIME CURVE.

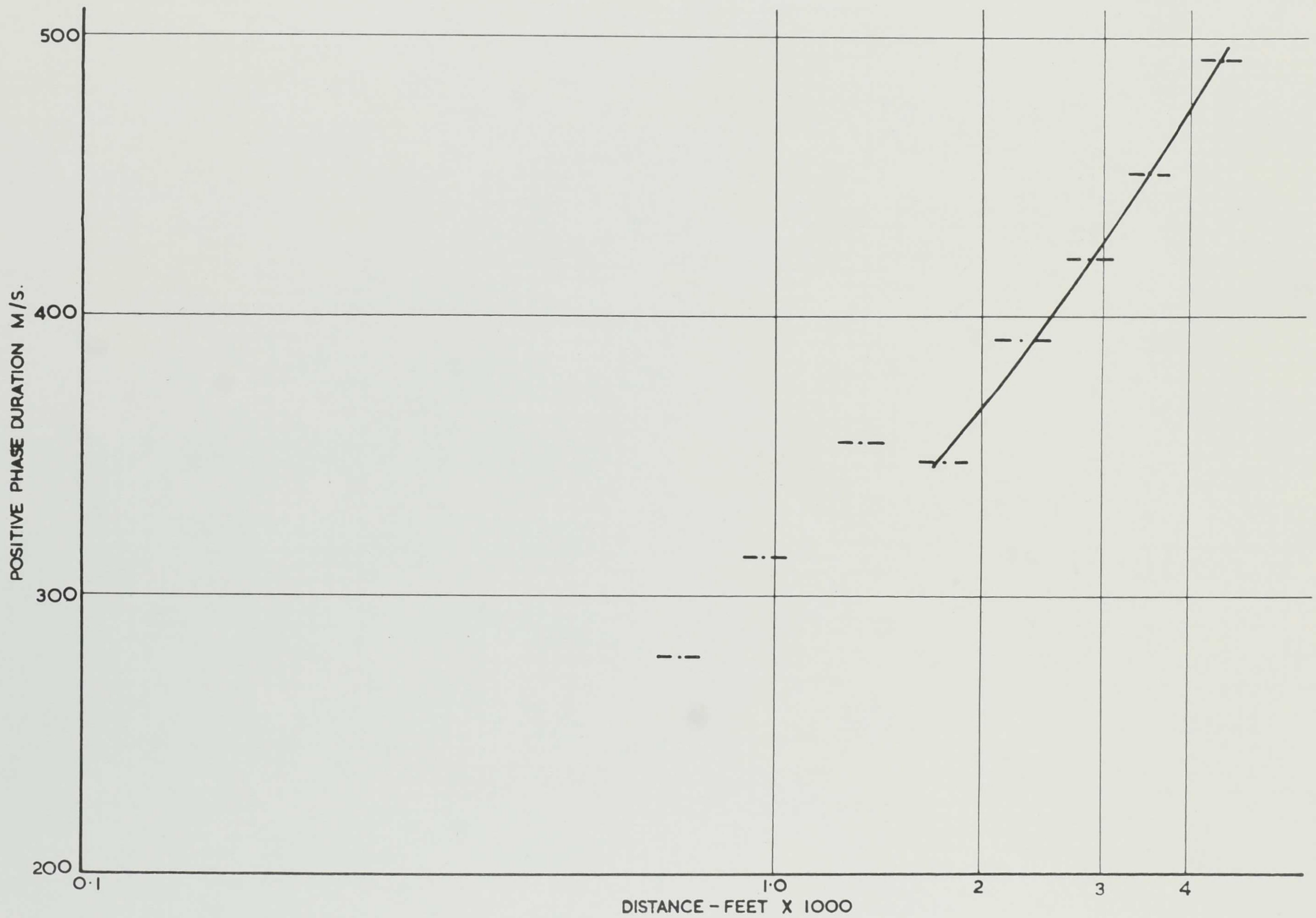

FIG. 36. ROUND 3. — DISTANCE / PHASE DURATION CURVE.

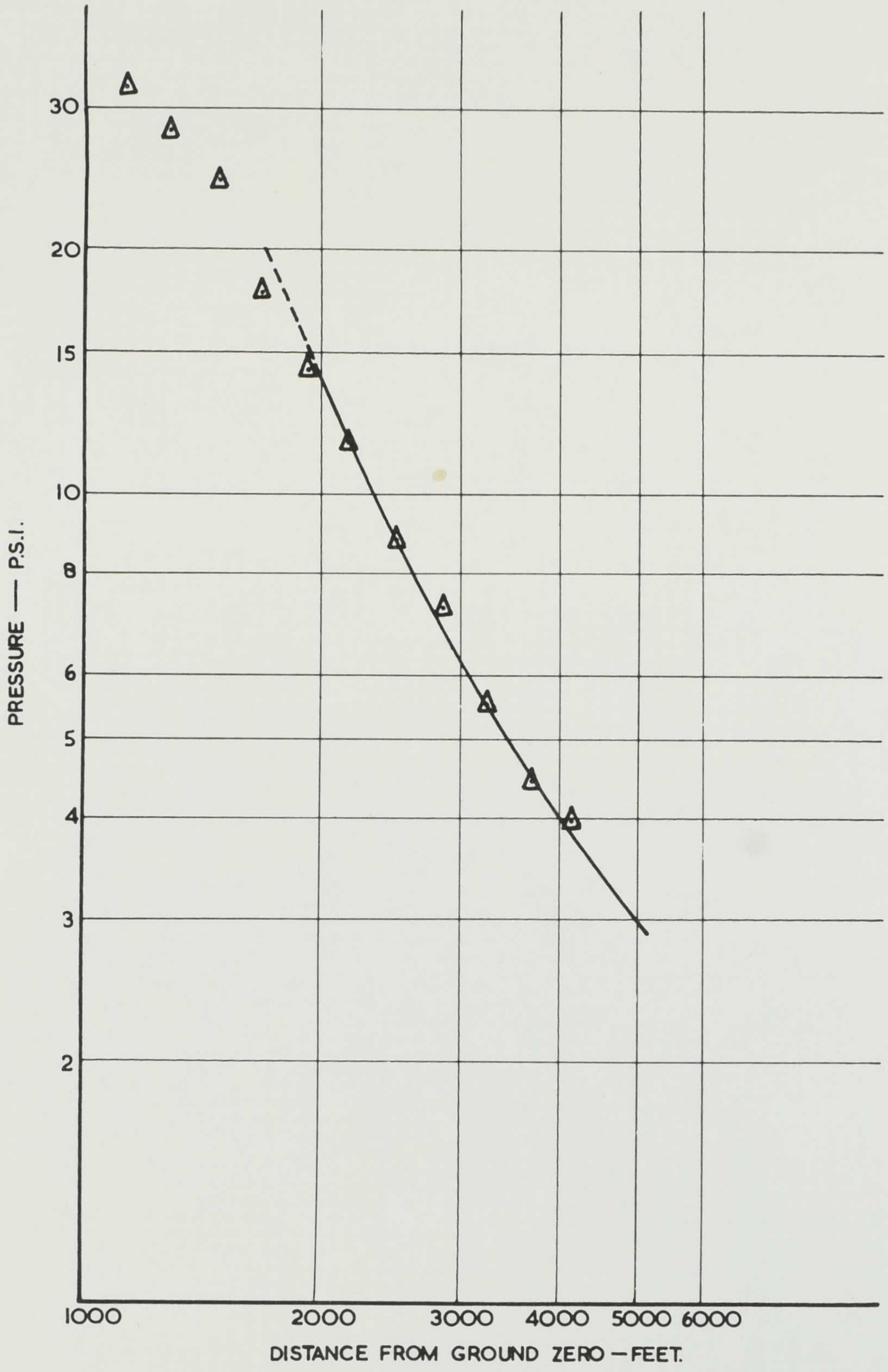

FIG. 37. ROUND 4.- PRESSURE / DISTANCE CURVE F.M.T. RESULTS.

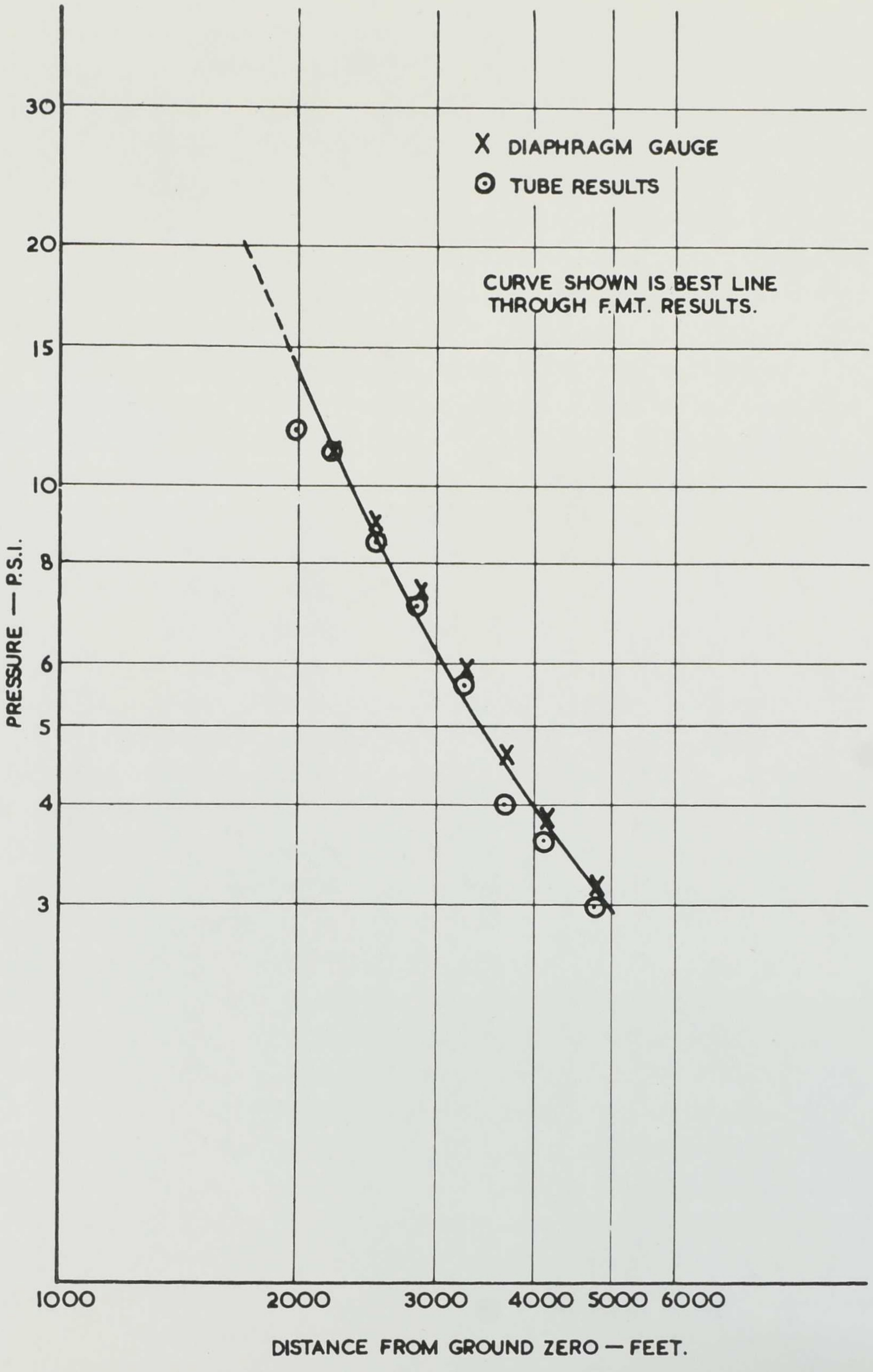

FIG. 38. ROUND 4.— PRESSURE/DISTANCE CURVE. DIAPHRAGM & TUBE RESULTS.

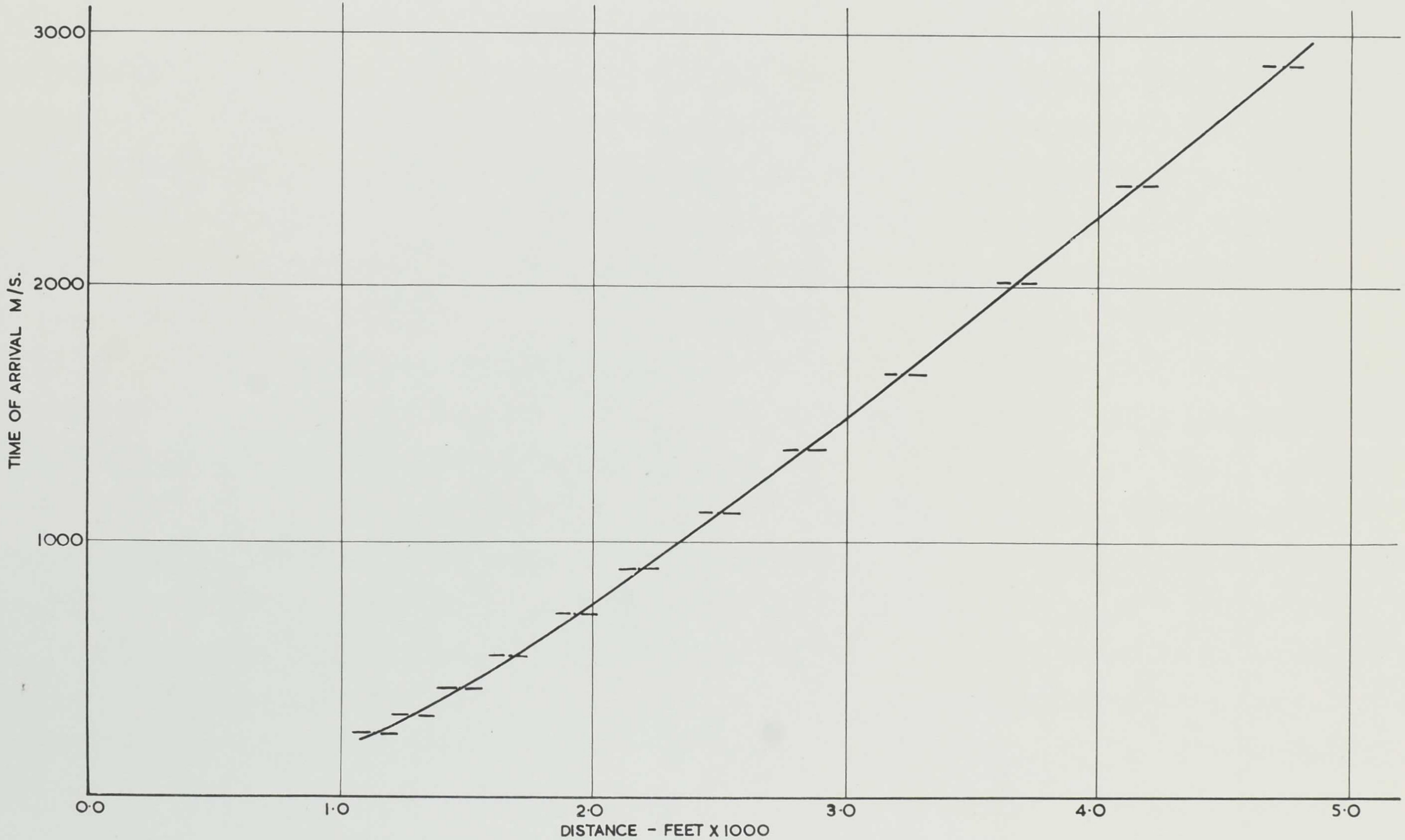

FIG. 39. ROUND 4. — DISTANCE/TIME CURVE.

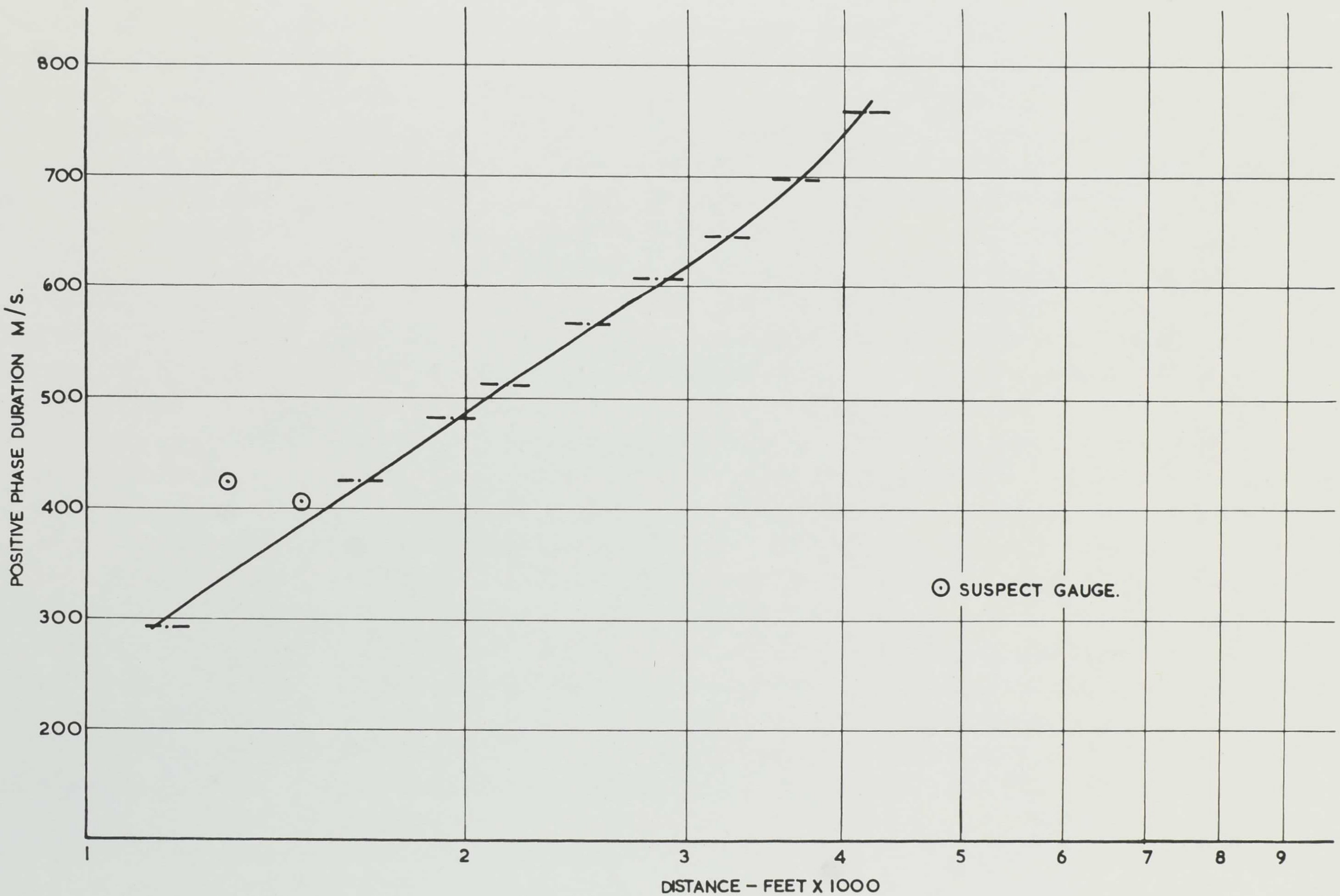

FIG. 40. ROUND 4.– DISTANCE / PHASE DURATION CURVE.

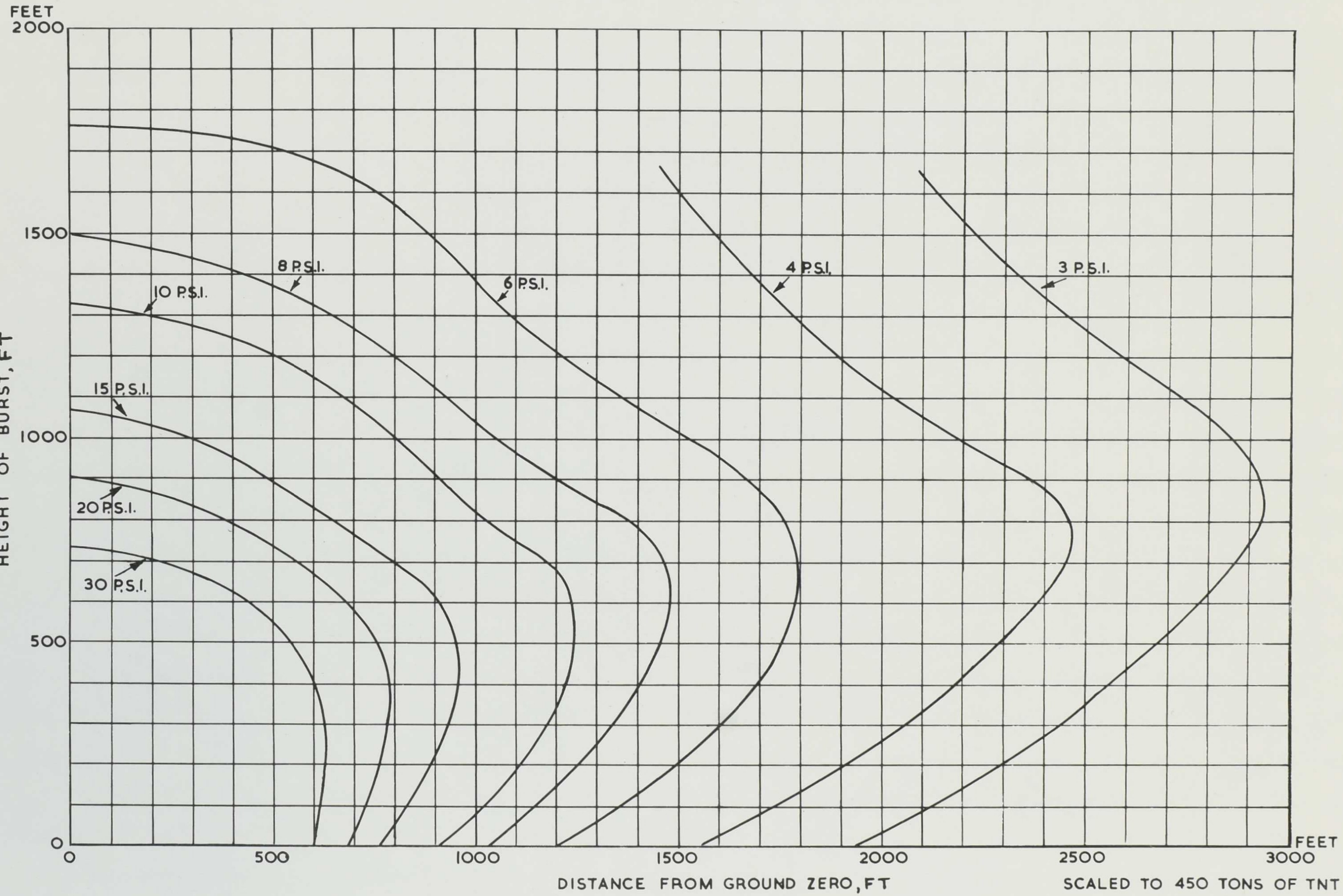

FIGURE 41. HEIGHT OF BURST: PRESSURE / DISTANCE DATA FOR 450 TONS OF T.N.T.

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UNITED KINGDOM ATOMIC ENERGY AUTHORITY

ATOMIC WEAPONS RESEARCH ESTABLISHMENT

AWRE REPORT No. T 4/65

B0153

OPERATION ANTLER

Air Shock Measurements

R. G. Turner

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A.W.R.E.,
Aldermaston, Berks.

(CLEARED FOR CANADA AND AUSTRALIA)

March 1965

Summary

On Operation Antler measurements were made of the shock overpressure/time relationship at sites down the main instrument lane, similar measurements at a few other isolated sites, and peak free air shock overpressure by a smoke rocket technique.

Three types of instrument were used. Two gave a pressure/time history of the shock wave at the recording site; the third, a measurement of the peak overpressure at the recording site.

The pressure/distance data for the precursor-free regions of the main instrument lanes have been compared with Foulness small charge data to give estimated total energy yields of:-

Round 1: 0.65 ± 0.05 kilotons **100 ft tower burst**

Round 2: 6.86 ± 0.36 kilotons **100 ft tower burst**

Round 3: 17.9 ± 0.9 kilotons. **1,000 ft balloon suspended air burst**

Time of arrival data, positive phase duration and positive phase impulse data are included. Canadian measurements of the free air shock using a smoke rocket trail technique are reported elsewhere.

NOTE: blast peak overpressure determined yields above have a source of error in the assumed conversion between blast yield and total nuclear yield (usually assumed to be 45% in UK reports, 50% in USA reports), because the surface portion of the blast wave is subject to thermal flash convective heating of the air near the ground surface even where a precursor does not occur, when this extra energy thus added from the thermal flash to the blast, boosts the effective blast yield, just as neutron heating of air around the fireball boosts blast.

TABLE 2

AIR BLAST DATA - STANDARDISED VALUES

Operation ANTLER Round No. 1 (1013 mb, 15^{o}C, still air) Date 14/9/57 Time of Firing 1435 hours IK

Height of Burst; 105 ft

Conditions of Burst; Tower

Type of Terrain; Limestone strata overlain with fine red sand

Correction Factors (after Wind Correction)

Distance $\left(\frac{Po}{1013}\right)^{1/3}$; 0.996.

Pressure $\frac{1013}{Po}$; 1.012.

Site No.	Gauge Type	Ground Range, ft	Peak Overpressure, p.s.i.	Remarks
AG 205	Tubes	1272	5.0	Times of arrival
AG 205	Tubes	1396	4.6	for wind
AG 206	Tubes	1570	3.7	correction
AG 208	Tubes	1767	3.4	obtained from US
AG 209	Tubes	2003	3.05	Capabilities of
AG 210	Tubes	2302	2.50	Atomic Weapons 1955

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TABLE 3

AIR BLAST DATA - STANDARDISED VALUES

Operation ANTLER Round No. 2 (1013 mb, 15^{o}C, still air) Date 25/9/57 Time of Firing 1000 hours IK

Height of Burst; 106 ft

Conditions of Burst; Tower

Type of Terrain; Limestone strata overlain with fine red sand

Correction Factors (after Wind Correction)

Distance $\left(\frac{Po}{1013}\right)^{1/3}$; 0.997. Time $\left(\frac{Po}{1013}\right)^{1/3}\left(\frac{273 + T}{288}\right)^{1/3}$; 0.995.

Pressure $\frac{1013}{Po}$; 1.009. Impulse (T × P); 1.004.

Site No.	Gauge Type	Ground Range, ft	Time of Arrival of Main Shock, s	Positive Duration, s	Peak Over-pressure, p.s.i.	Positive Impulse, p.s.i. s	Remarks
AG 411	FMT	1645	0.643	0.395	12.3	1.66	
AG 412	FMT	1844	0.777	0.433	10.5	1.66	
AG 401	FMT	2044	-	-	8.35	-	No time trace
AG 402	FMT	2203	1.042	0.492	7.28	1.45	
AG 403	FMT	2452	1.231	-	6.29	-	Recorder running erratically
AG 404	FMT	2662	1.397	0.518	5.25	1.21	
AG 405	FMT	2941	1.613	0.571	4.74	1.05	
AG 406	FMT	3210	1.828	0.586	4.05	0.91	
AG 407	FMT	3629	2.173	0.585	3.49	0.85	
AG 408	FMT	4077	2.548	0.645	2.71	0.78	
North Base	FMT	20936	-	-	0.28	-	Recorder hand switched

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TABLE 5

AIR BLAST DATA - STANDARDISED VALUES

Operation ANTLER Round No. 3 (1013 mb, 15°C, still air) Date 9/10/57 Time of Firing 1615 hours IK

Height of Burst; 992 ft

Conditions of Burst; Triple balloon supported

Type of Terrain; Limestone strata overlain with fine red sand

Correction Factors (after Wind Correction)

Distance $\left(\frac{Po}{1013}\right)^{1/3}$; 0.992. Time $\left(\frac{Po}{1013}\right)^{1/3}\left(\frac{273 + T}{288}\right)^{1/2}$; 1.024.

Pressure $\frac{1013}{Po}$; 1.025. Impulse (T × P); 1.050.

Site No.	Gauge Type	Ground Range, ft	Time of Arrival, s		Positive Duration, s	Time to Second Shock, s	Peak Over-pressure, p.s.i.		Positive Impulse, S_2, p.s.i. s	Remarks
			Precursor	Main Shock			S_1	S_2		
AG 516	FMT	1353	0.435	-	0.545	0.904	30.1	5.88	6.09	
AG 517	FMT	1601	0.523	-	-	1.015	18.0	-	-	Gauge disconnected before end of positive phase
AG 512	FMT	1800	0.621	-	-	1.094	13.9	5.48	-	Gauge disconnected before end of positive phase
AG 513	FMT	2077	-	-	-	-	7.17	-	-	Fault occurred at time zero. No time trace
AG 514	FMT	2395	0.947	-	0.536*	1.481	8.50	0.221	2.42*	*Leaky gauge
AG 515	FMT	2693	1.157	-	0.743	1.676	9.99	0.219	3.12	
AG 501	FMT	2991	1.366	-	0.767	1.890	9.73	0.233	3.05	
AG 503	FMT	3835	-	2.013	0.709*	2.495	6.32	0.650	2.08*	*Leaky gauge
AG 504	FMT	4281	-	2.363	0.866	2.827	5.84	0.678	2.29	
AG 505	FMT	4827	-	2.785	0.943	3.240	4.73	0.548	2.11	
AG 506	FMT	5423	-	3.248	0.980	3.700	3.67	0.449	1.87	
AG 507	FMT	6068	-	3.782	1.06	4.212	3.23	0.369	1.65	
North Base	FMT	24798	-	-	-	-	0.54	-	-	Recorder hand switched
TR 517	FMT	1835	-	-	0.532	-	11.8	-	3.26	
TR 513	FMT	2265	-	-	0.701	-	12.0	-	3.75	

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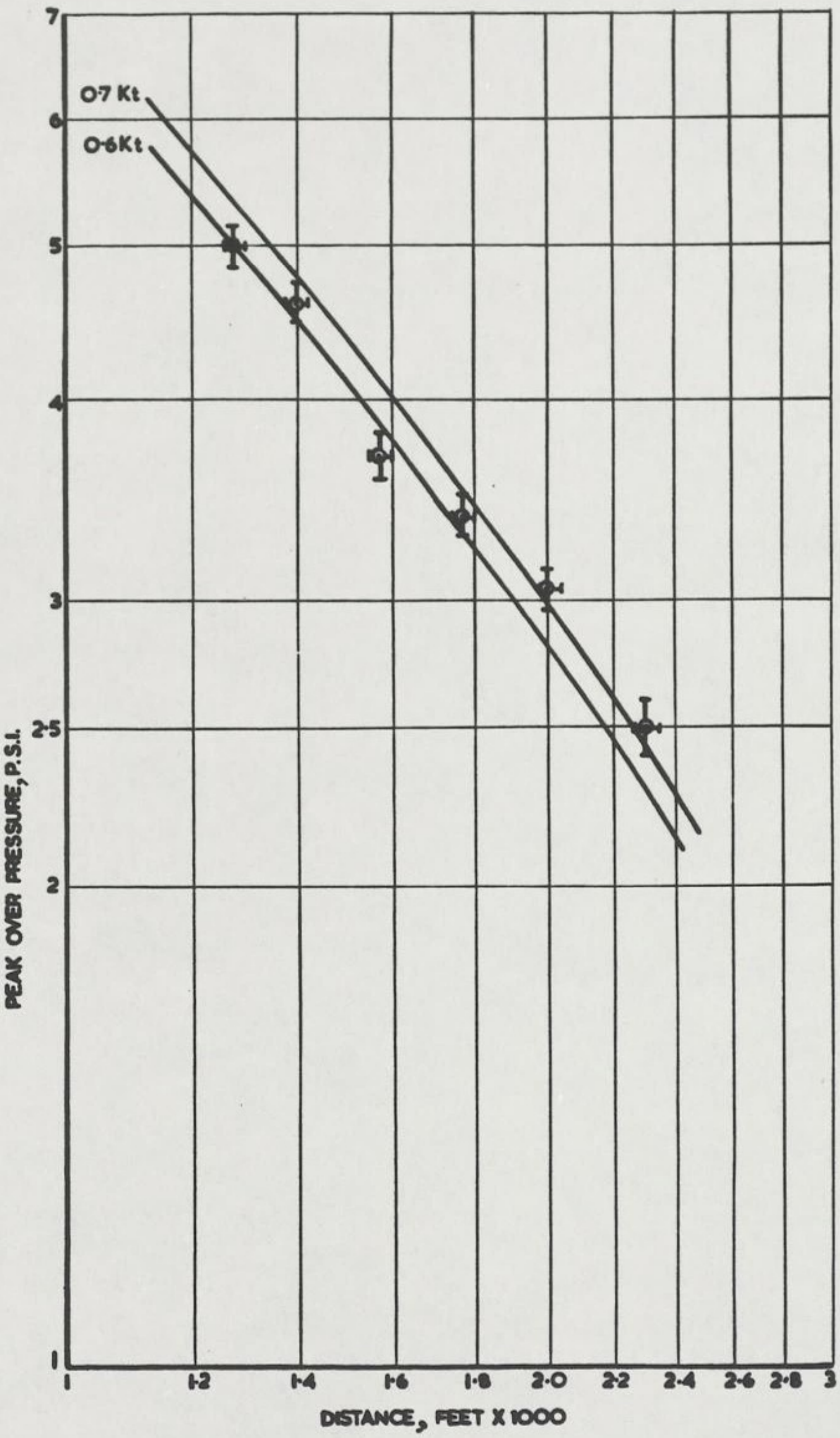

FIGURE I. ROUND I. PEAK OVER PRESSURE

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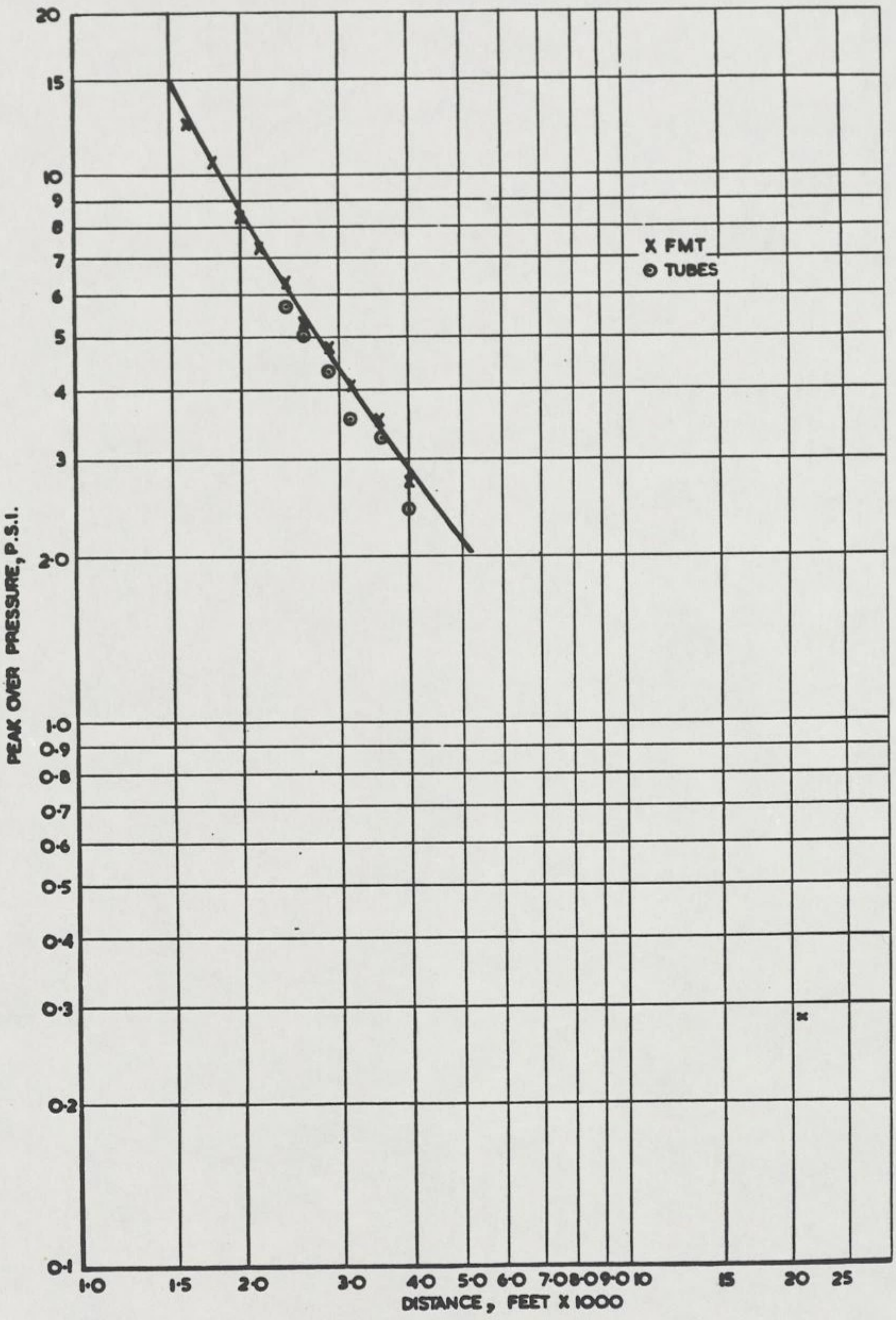

FIGURE 2. ROUND 2

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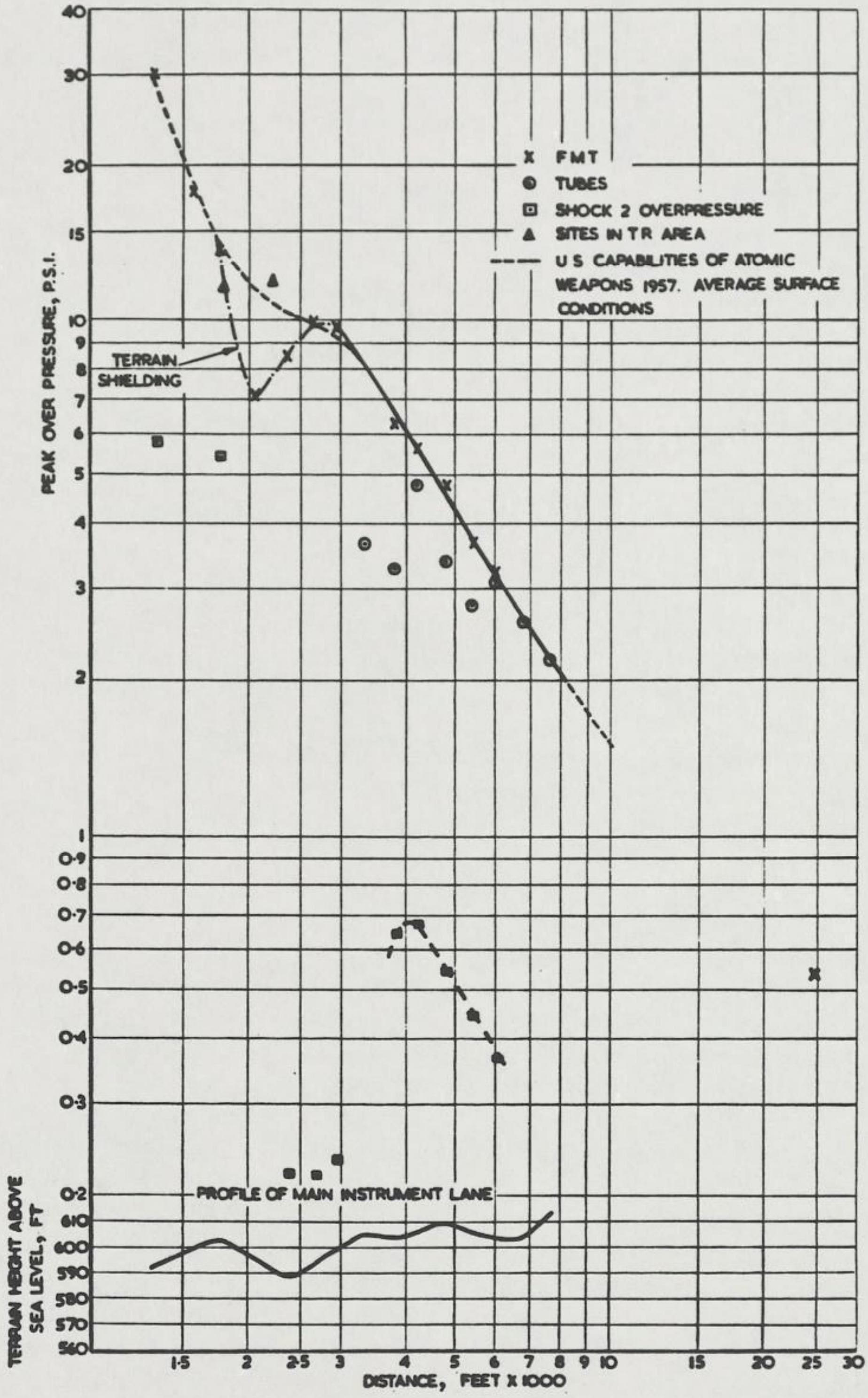

FIGURE 6. ROUND 3

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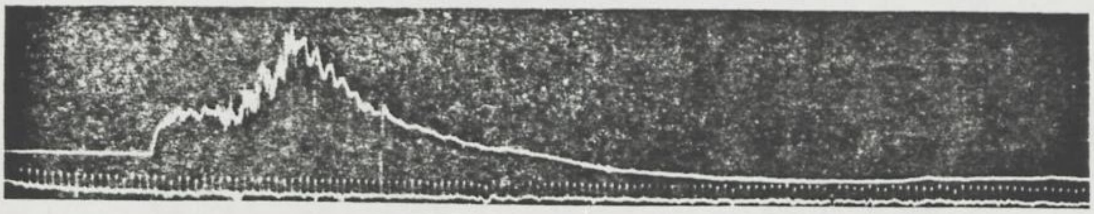
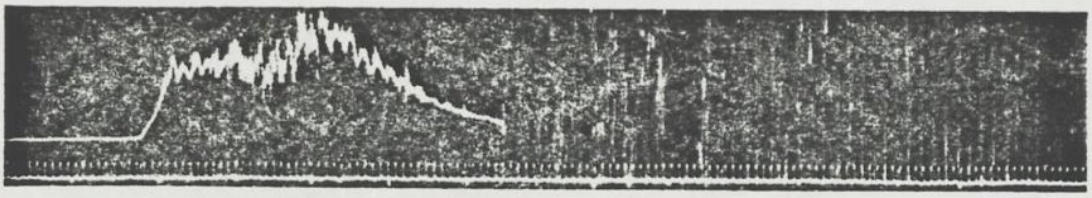
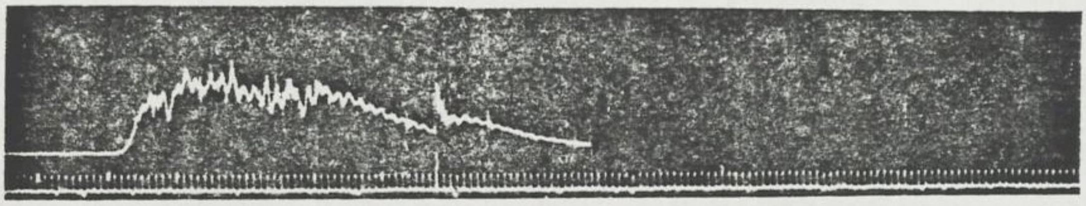


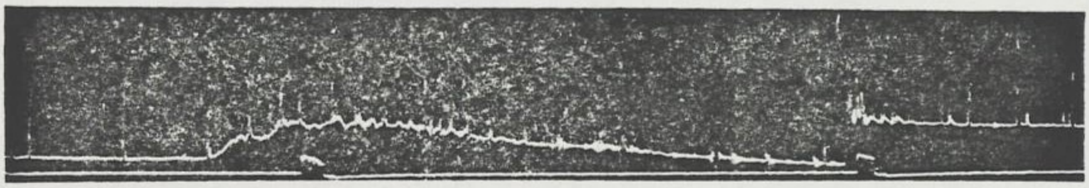
AG 516 1 353 FT 30·1 P.S.I.



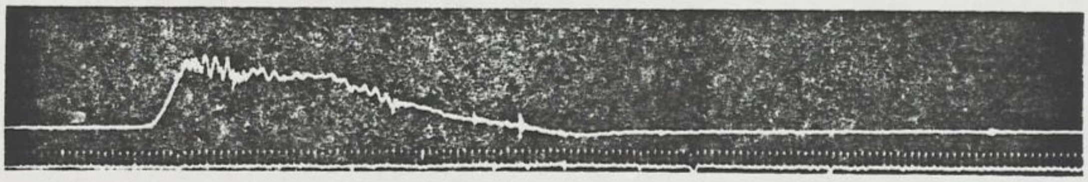
AG 517 1 601 FT 18·0 P.S.I.



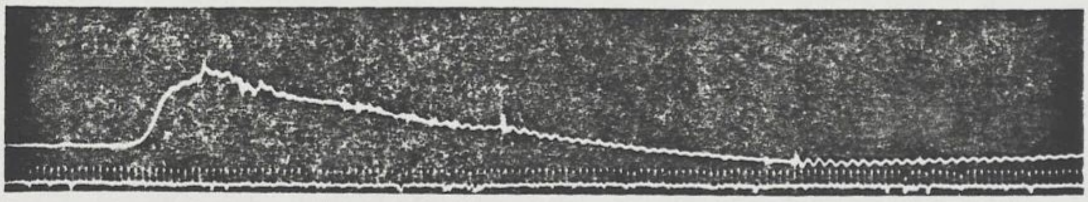
AG 512 1 800 FT 13·9 P.S.I.



AG 513 2 077 FT 7·17 P.S.I.



AG 514 2 395 FT 8·50 P.S.I.



AG 515 2 693 FT 9·99 P.S.I.

FIGURE 12 ROUND 3

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[redacted]

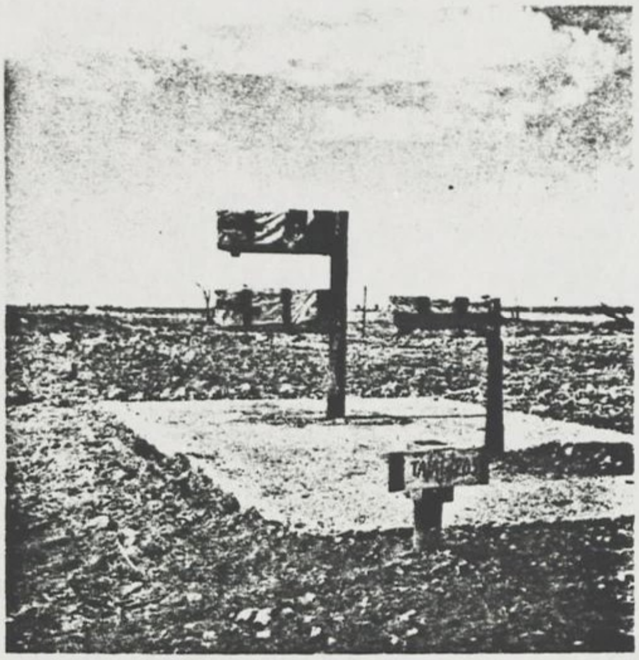

FIGURE 15. SITE AG 205 ROUND I. TYPICAL INSTALATION

FIGURE 16. SITE AG 513 ROUND 3. 2077 FT FROM GZ LOOKING FORWARD TO THE RIDGE AT 1700 FT

[redacted]

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SECRET

SECRET U.K. EYES ONLY

UK U/C 15/3/85 AB/Safety/2. 0141 11/4/85

Reference A8/633/58/CAA

MINISTRY OF DEFENCE SC (NUC) 2 LONDON S.W.1.

6056 Permanent Proving Ground Trials 0171 JC

U/C wrt Def Nuc Tech info 23/1/85

Downgraded to. UNCLASSIFIED

DEFE 16/443

Admiral P.W.Brooking

Co 60 pellets found at Maralinga

Halliday rang me this morning to say that Myers has been enquiring about the Co60 pellets found at Maralinga by Turner. I have tried, without success, to ring Myers to find his source of information and the reason why he is pursuing the matter. The facts are as follows:-

Co60 was used at Antler as a detector. With some difficulty I obtained permission from the Director to inform Titterton (as Chairman of the Safety Committee) that we intended to use such an indicator. Titterton was entirely sympathetic, raised no difficulties, realised that we were not adding any real hazard, and agreed that the information should go no further on the Australian side. Recently Turner, the Australian who is responsible for Health Physics at Maralinga in the inter-trial period, claims to have found Co60 in some pellets which he has collected and which we have arranged should be sent back to U.K. As soon as I heard of this I wrote to Titterton stating what the position was and suggesting that it would be as well if information on this subject were not extended any further in Australia. I have not as yet had any reply from him.

I shall not have an opportunity to get in contact with Myers today. Tomorrow evening I leave for Risley and expect to be in again on Friday. You may think it worthwhile to get in touch with Myers. The fact that he is asking questions on the subject suggests that the information has already received a wider circulation than I thought it would.

/Since

12th August, 1958

SECRET

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Since dictating the above I have had a call from Frankie Lloyd who raised the matter of Co60 amongst other things. It appears that Turner has reported to Dick Durance in addition to reporting here. In doing so I think Turner has misconstrued his terms of reference which were to report in the first instance to A.W.R.E. The correspondence will be sent down here by Frankie. I hope that I shall shortly have a reply from Titterton but at present I do not know how to get in touch with him. I have asked Mrs. Prosser to find from Australia House where Titterton can be contacted. If it is necessary to correspond with the Australian Department of Supply or the Range Commander, I should much prefer to do so in terms agreed with Titterton, rather than to write indepdently.

C.A.A.

C. A. Adams
C.T.